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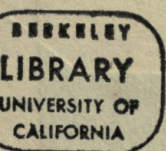


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ANNOUNCEMENT

The purpose of this announcement is to inform the public of the results of the recent survey conducted by the Department of the Interior, Bureau of Land Management, regarding the status of the public lands in the State of California. The survey was conducted by the Bureau of Land Management, and the results are being published in a report which is being distributed to the public. The report contains information regarding the status of the public lands, including the amount of land that is available for sale, the amount of land that is reserved for other purposes, and the amount of land that is being used for other purposes. The report also contains information regarding the status of the public lands in the State of California, including the amount of land that is available for sale, the amount of land that is reserved for other purposes, and the amount of land that is being used for other purposes.

A detailed description of the survey and the results of the survey is contained in the report. The report is being distributed to the public in order to provide them with the information they need to make decisions regarding the public lands. The report is being distributed to the public in order to provide them with the information they need to make decisions regarding the public lands. The report is being distributed to the public in order to provide them with the information they need to make decisions regarding the public lands.

The Department of the Interior, Bureau of Land Management, is responsible for the management of the public lands in the State of California. The Bureau is committed to providing the public with the information they need to make decisions regarding the public lands. The Bureau is committed to providing the public with the information they need to make decisions regarding the public lands.

ANNOUNCEMENT.

THE present Volume completes this Series of Tracts on Physical Science, and its applications. In bringing the Work thus to a close, the purpose of the Author and Publishers has been to confine the collection within such a limit of bulk and price as may be compatible with the leisure and the means of the great majority of its Subscribers. The whole series is now comprised in the moderate limits of twelve single volumes, in ornamental boards, at 18s., or six double volumes, in cloth, lettered, at 21s.

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1901



EDITED BY

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The numbers of the paragraphs and figures of the "PRE-ADAMITE EARTH," are continuous with those of the "CRUST OF THE EARTH," in volume XI., of which subject the "PRE-ADAMITE EARTH" is the continuation and development. This statement will explain what might otherwise seem incorrect in the numbering of the paragraphs and figures.

ERRATA.

Pre-Adamite Earth, page 85, paragraph 362, line 2, for "160," read "163."
 „ „ page 86, line 10, for "Equitaceæ," read "Equisetaceæ."

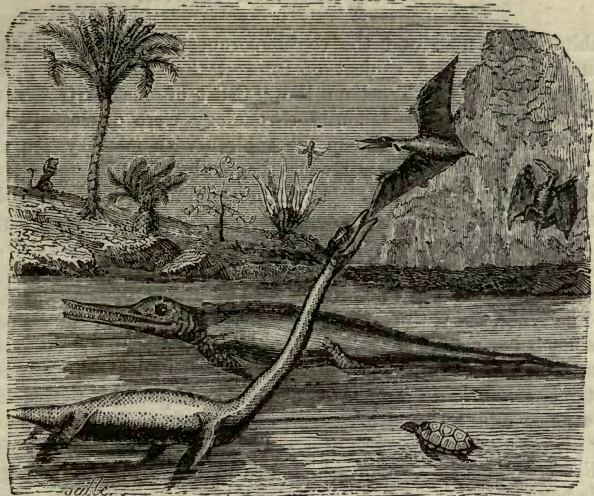


Fig. 161.—ILLUSTRATION OF THE ANIMAL AND VEGETABLE KINGDOMS
DURING THE JURASSIC AGE.

THE PRE-ADAMITE EARTH.

CHAPTER I.

186. Interest of the subject.—187. Recapitulation.—188. Original division of the land and water.—189. Uniform temperature at all latitudes.—190. This temperature at first too elevated for organic life.—191. Its gradual reduction.—192. Series of convulsions.—193. Depositions of organic remains.—194. First organic creation after the fourth convulsion.—195. The latest catastrophe of this kind.—196. Method of determining the age of mountains.—197. Ranges of similar date parallel.—198. Their nomenclature.—199. Method of ascertaining the outlines of land and water at each geological epoch.—200. M. Elie de Beaumont's seventeen mountain systems.—201. Their directions and denominations.—202. Manner in which they are grouped.—203. Plan of these systems in Europe.—204. Their geological dates.—205. System of Vendée.—206. System of Finistère.—207. System of Longmynd.—208. System of Morbihan.—209. System of Hundsruck.—210. System of the Ballons.—211. System of the North of England.—212. System of Hainault.—213. System of the Rhine.—214. System of Thuringerwald.

186. THE history of our planet before it was clothed with that variety of vegetation which now adorns it, and became the

THE PRE-ADAMITE EARTH.

habitation of man and the contemporaneous tribes of animals, cannot fail to be a subject of interest the most exciting and profound. In our Tract on the "Crust of the Earth," some glimpses of this pre-Adamite chronology were disclosed. We purpose at present to resume the subject with more system and detail, assuming that our readers have already rendered themselves familiar with the facts, phenomena, and principles which were there stated and explained.

187. Before we enter upon this curious narrative, however, it will be useful to recapitulate the great facts which will be brought in more detail before the reader.

The globe, consisting originally of matter in a state of igneous fusion, being put in a state of rotation, assumed, as a necessary mechanical consequence of that motion, the form which it still retains, called in geometry that of an oblate spheroid, flattened at the poles and bulging out at the equator; the sections made by planes passing through the axis of rotation being therefore ellipses, the longer axes of which are diameters of the equator. We have shown in former Tracts that the eccentricity or degree of the oval shape which characterises these ellipses depends immediately upon the velocity of rotation, so much so that, by mere mathematical calculation, the form of the ellipse has been deduced *a priori* from that velocity, and the form thus calculated has been found to correspond with the actual shape of the earth.

By the gradual process of cooling produced by radiation the surface of the earth became solidified, a thin skin of solid matter being first formed upon it, which, as the cooling continued, became gradually thicker, the increase of thickness being produced by more and more solidified matter collected on its inner surface. This thickness may be said therefore to have increased from the outside inwards. At first the temperature was necessarily such that water could not exist upon it in the liquid state, but according as the temperature of the surface became gradually lower, the aqueous vapour till then sustained in the atmosphere was more or less condensed and precipitated, forming upon it an ocean of uniform depth extending over the entire surface.

188. If no convulsion had taken place the earth would have continued in this state. It would have been one universal ocean undiversified by land, and the human race could never have existed upon it. It follows, therefore, that before terrestrial tribes were created the globe must have been of necessity the theatre of various catastrophes, by which the land was raised above the waters, and by which a state of things was established, more or less analogous to that which geography now presents to us. It was necessary, in a word, that the "dry land should appear."

RECAPITULATION.

Extensive observation on the condition of the crust of the earth proves that such forms were not assumed definitely and permanently at once, but that they underwent a long succession of changes, in the course of which the outlines of land and water were frequently varied: what was land at one time became the bottom of the ocean at another, and what was the bottom of the ocean at one time, rising to the surface, assumed the forms of continents and islands at another.

It would be easy to show, by an analysis of the effects produced by such a succession of catastrophes, that they all tended to one definite end; namely, the final adaptation of the earth for the dwelling-place of the human race, and its contemporaneous tribes.

After the superficial temperature had fallen sufficiently low to allow of the deposition of water upon the surface, and the formation of an universal ocean, a series of convulsions commenced, each of which was produced by the agency of the matter in igneous fusion contained within the solid shell of the earth. This matter acting unequally against the inner surface of the shell cracked it from time to time, producing fissures, through which the igneous pasty matter issued, cooling and solidifying when exposed to the external atmosphere. Each convulsion necessarily changed the relative levels of different parts of the solid surface, and this was attended with a corresponding change in the distribution of the waters of the ocean. Upon the occurrence of each phenomenon, these waters would rush with furious impetuosity over such parts of the land as would fall to a lower level, while at other places the solid bottom of the ocean would rise above the surface of the waters, forming new continents and islands. Such catastrophes must not be regarded as either conjectural or imaginary. They have, on the contrary, left on the earth visible traces by which their occurrence has not only been demonstrated, but even their dates have been geologically ascertained, so that we are enabled to state the order in which they occurred.

189. For a long period of time, during which these catastrophes were developed at intervals, the superficial temperature depended infinitely more upon the internal heat transmitted to the surface through the crust, than upon the effects of solar radiation. It must be remembered, that, so far as the superficial temperature would depend upon the heat received from the interior through the crust, the temperature would be everywhere the same. Thus it would affect the poles and the equator equally, and would be equally diffused over all latitudes; but, on the contrary, so far as the temperature would depend on solar radiation, it would vary with the latitude, as it does at present, being greatest between the tropics, and least

THE PRE-ADAMITE EARTH.

within the polar circles. But, as has been just observed, during the early periods of the history of the earth, to which we now refer, the influence of internal heat predominating enormously over that of solar radiation, the effects of the latter were wholly effaced, and, consequently, the superficial temperature was uniform at all latitudes.

190. For a long period after the commencement of superficial solidification, this temperature was far above the limit compatible with the existence of any form of organic life, animal or vegetable; and, consequently, during this interval the globe was a mere waste, unanimated by life and unadorned by vegetation. Meanwhile, nevertheless, a succession of changes took place, the effects of which have remained so visibly traced upon the earth to the present day, that geologists have been enabled to pronounce not only their existence but their order. Four times the solid crust was cracked, and the internal fluid matter issued through the fissures, forming four systems of mountain-ranges, which still exist to attest these remarkable facts in the primitive history of our planet.

191. At length the temperature being reduced to a point compatible with organised life, creative power began to be manifested. The earth was peopled with animals and clothed with vegetation, but these animals and this vegetation differed altogether from those which now animate and cover the globe. They were, however, adapted by divine wisdom to the then condition of the earth, the temperature being not only greater than any which prevails at present, but, as has been stated, uniform at all latitudes.

192. After this, a like succession of convulsions took place, long intervals of time intervening, by each of which the relative levels of the land were changed, and consequently the distribution of the waters of the ocean completely altered. Such changes implied universal inundations, which involved the destruction of all animated nature, animal as well as vegetable. In short, a succession of deluges must have attended such convulsions, each deluge destroying all the tribes of animals and plants which existed on the globe at the time of the catastrophe.

193. After each of these convulsions, the waters at first turbid, and holding in suspension great quantities of matter washed away and eroded from the former land, as well as enormous quantities of the remains of the animals and plants previously existing, would, after a time, become tranquil, and then a process of vast importance to the preservation of the history of the globe would take place. The organic remains of animals and plants suspended in the waters would be deposited at the bottom

GRADUAL REDUCTION OF TEMPERATURE.

of the ocean, and over them would subside also the solid matter sustained in a state of comminution in the waters. The remains would thus be buried in strata sensibly horizontal, and, being covered up by the earthy and mineral matter which would subside from the waters, they would be protected from the destructive action of air and water thereafter, and would thus be preserved to future generations as records of the past history of the earth.

In the interval of tranquillity following each such deluge, creative power was again brought into operation, and the earth was repopled with animated creatures, and reclothed with vegetation; but in all cases the animals and plants composing the new kingdoms of nature, though agreeing with those recently destroyed in their classes and generic characters, differed from them altogether in their species. In short, a new kingdom of nature was produced, but constructed upon the same general principles.

194. By researches made in the crust of the earth, and careful analyses of the constitution of its strata and of the animal remains contained in them, geologists have ascertained, with a high degree of probability, if not with absolute moral certainty, that subsequently to the first appearance of the forms of animal life, which, as has been stated, took place after the fourth great convulsion of the globe, there were at least twenty-eight successive convulsions of a like nature, each of which was attended with the complete destruction of the animals and plants which existed upon the globe, their remains being buried in the manner already stated under the sedimentary deposits made by the new oceans which followed the crisis.

The actual occurrence of these several convulsions, and of the existence of the successive animal and vegetable kingdoms, differing one from another in the species of which they were constituted, has been proved by geologists by two species of evidence, one depending on the condition of the stratification, by which it has been shown that many of these catastrophes were attended with the elevation of systems of mountains which still exist upon the surface of the earth, while others, though not indicated by mountain ranges, are rendered evident by certain discordances and disturbances in the state of the strata. These catastrophes have also been indicated by the discovery of the buried remains of each of the several animal and vegetable kingdoms here mentioned.

195. In fine, after the latest of the catastrophes, when the last strata of the tertiary formation were deposited, the most recent exertion of creative power took place, and the globe was peopled with the tribes which now inhabit it, including the human race.

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Such is a brief and rapid sketch of the phenomena which form the subject of the pre-Adamite history of the globe, which it is our present purpose briefly to sketch.

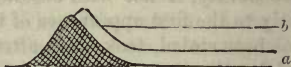
196. The manner in which the geological age of mountain-ranges is determined by the state of the strata observed upon their slopes has been already explained, but this is so important an element in our present inquiry, that it may be useful to recapitulate it and present it to our readers under another aspect.

When we see anywhere the sedimentary strata composing the crust of the earth inclined, we can pronounce with certainty that they have been disturbed from their original position which was horizontal, and that, in short, an elevation has taken place by a force acting from beneath. So far as relates to the strata thus inclined, the epoch of the catastrophes would be undetermined, but if at the foot of the mountains we find other strata *abc*, fig. 112,

Fig. 112.



Fig. 113.



horizontal, it becomes evident that the elevation of the former must have taken place before the deposition of the lowest of the latter, since the latter are in the position in which they naturally subsided from the waters.

The geological date of the elevation in this case would be between the period of the strata, which are elevated and inclined, and the lowest, *a*, of the horizontal strata. In the case of all mountain-ranges, data of this kind, determining the geological epochs of the disruption which produced them, are supplied. In some places we see for example the stratum *a*, heaved upwards, and *b* horizontal, fig. 113. In such cases the date of the catastrophe is posterior to the deposition of *a*, and anterior to that of *b*.

Fig. 114.

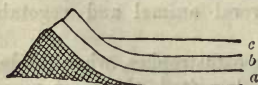


Fig. 115.



In other cases, both *a* and *b*, fig. 114, are uplifted and inclined, but *c* is horizontal, and it is accordingly inferred, that the date

AGE OF MOUNTAIN SYSTEMS.

of the catastrophe was between the deposition of the strata *b* and *c*.

In like manner if it be found that while the strata *a*, *b*, and *c* are all uplifted and inclined, *d* is horizontal, fig. 115, it is inferred that the date of the catastrophe was between the periods of the deposition of *d* and *c*, and so on.

It will be evident that we have here assumed that the strata *a*, *b*, *c*, *d*, &c. are in the natural succession of strata, in the order of geological time, found in any complete section of the earth's crust, in which no strata are deficient.

197. It must also be observed that the direction of the inclination of the strata thus uplifted, corresponds with and determines the direction of the ridge of mountains upon the flanks of which they lie, and it has resulted from the extensive and profound researches of M. Elie de Beaumont, that the chains of mountains in general whose directions are parallel have the same geological date, as is proved by the strata inclined upon their sides and horizontal at their base. Mountain ranges, therefore, which until the discovery of this important law were regarded as geologically distinct and independent, are now brought into the same system. Each mountain system, therefore, must be regarded not as a single chain, but as a number of parallel chains which may be near or distant from each other within any assignable limits. It may also be observed, that the parts even of the same chain are not always continuous, but may be broken by intervals along which, as it were, the crust sinks to the level of the surrounding plain.

198. The systems of mountains which have thus been grouped according to their geological dates have usually received denominations from some remarkable locality in which their prevalence is most conspicuous. Thus one is called the system of the Pyrenees, another the system of the principal Alps, another the system of the western Alps, and so on.

The different convulsions which have taken place upon the surface of the globe, and which have produced the several mountain systems, seem to have been always sudden. In effect at some distance from the place where the discordance of the stratification manifests former convulsions, the same strata are found concordant and horizontal, from whence it follows, that in such cases the sedimentary deposition has not been suspended, the disturbance of the crust has been local, and the interval during which it has prevailed has necessarily been short.

199. During each successive geological period, the earth has been differently divided into land and water, the continents and islands of one period being submerged during another, and the

parts submerged becoming dry land. During each period the deposition of strata corresponding to it, has been of course confined to such parts of the earth only as were covered by water, and hence we are able to trace the geographical limits of sea and land, by tracing the limits of the deposits characteristic of each stratum.

Thus, during the Silurian period, the Silurian strata have been deposited only on those parts of the globe which were during that period covered by water, but not on those which formed the land. When we use the expression, therefore, the *Silurian sea*, we must be understood to mean that portion of the globe which, during the Silurian period, was covered by water, and those portions must necessarily be co-extensive with and limited by Silurian deposits. In the same manner during the Cretaceous period, the globe, as before, consisting of land and water, the cretaceous deposit was made only in those parts which were then covered by water, and formed the bottom of what is called the *Cretaceous sea*; the other parts of the earth, which at that epoch formed the land, being consequently destitute of the cretaceous strata.

In the same sense is to be understood the expressions, the *Triassic sea*, *Jurassic sea*, *Tertiary sea*, and so on.

The absence, therefore, of any particular deposit in an extent more or less considerable of the crust of the earth, indicates that the subjacent deposit was above the level of the sea, and formed an island or continent more or less elevated during the period in which the absent deposit was made. Thus, for example, an extensive plateau in the centre of France must have been dry land from the most remote geological epochs; and at the epoch of the formation of the deposit which constitutes the present Paris basin, the greatest part of Europe must have been dry land, while Paris and a large tract surrounding it, as well as Bordeaux and the surrounding regions, were covered by the sea, as will be more fully explained hereafter.

But it happens also that the parts which thus prove to have been dry land at a certain geological epoch, have been afterwards covered by more modern sediments; from whence it follows that they must have subsequently sunk beneath the ocean, so as to receive these new deposits. It is by such subsidences of the land that some of the geological convulsions, whose traces will be hereafter noticed, have been explained.

200. According to the results obtained from the researches of M. Elie de Beaumont, it appears from a comparison of the various mountain ranges of Europe, and from an examination of the strata upon their slopes and at their bases, that since the solidifi-

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cation of its crust this part of the globe has undergone at least seventeen distinct convulsions, each of which has produced a mountain system, the mean direction of which has been ascertained, and is characteristic of it. These seventeen systems have received denominations, as already mentioned, from some localities in which their prevalence is most conspicuous, and the directions which characterise them are indicated in the following diagram.

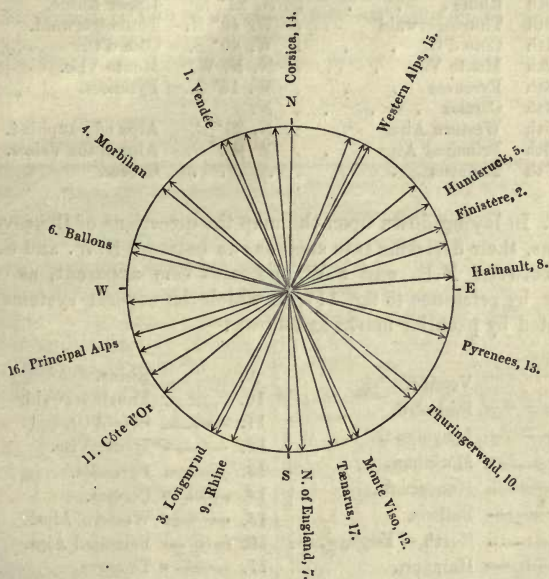


Fig. 116.—Directions of the principal Mountain-systems.

201. The order in which these several systems have been elevated is indicated by the numbers placed at one extremity of the lines indicating their direction, and these directions are expressed with more numerical precision in the following table, where W. 21° S. means a point 21° south of west; N. 23° E., a point 23° east of north; W. 38° N., a point 38° north of west, and so on. The places indicated in the second column are those from which the system takes its name, and those indi-

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cated on the fourth column those at which its direction has been determined.

1st	Vendée	N. N. W.	Vannes.
2nd	Finistère	W. 21° S.	Brest.
3rd	Longmynd	N. 23° E.	Vannes.
4th	Morbihan	W. 38° N.	Vannes.
5th	Hundsruck	W. 31° S.	Bingerloch.
6th	Ballons	W. 15° N.	Ballons.
7th	North of England . .	N. 5° W.	North of England.
8th	Hainault	W. 5° S.	Netherlands.
9th	Rhine	N. 21° E.	Upper Rhine.
10th	Thuringerwald . . .	W. 40° N.	Thuringerwald.
11th	Côte d'Or	W. 40° S.	Côte d'Or.
12th	Monte Viso	N. N. W.	Monte Viso.
13th	Pyrenees	W. 18° N.	Pyrenees.
14th	Corsica	N.	
15th	Western Alps	N. 26° E.	Alps of Dauphiné.
16th	Principal Alps . . .	W. 16° S.	Alps of the Valais.
17th	Tænarus		Greece.

202. In laying down upon the map the directions of the several systems, their divisions into such as run between N.W. and S.E., and between N.E. and S.W., becomes very apparent, as will appear by reference to fig. 117, in which the several systems are indicated by peculiar marks as follows:—

1. —°°— Vendée.	9. ——— Rhine.
2. ——— Finistère.	10. ~~~~~ Thuringerwald.
3. -.-.-.- Longmynd.	11. ——— Côte-d'Or.
4. °°—°° Morbihan.	12. ——— Monte Viso.
5. ~~~~~ Hundsruck.	13. ——— Pyrenées.
6. ~~~~~ Ballons.	14. +++++ Corsica.
7. North of England.	15. °°°°° Western Alps.
8. ——— Hainault.	16. ~~~~~ Principal Alps.
	17. °°°°°°° Tænarus.

203. The systems directed between the N.W. and S.E. run from the Rhine towards Provence and Brittany, and those between the N.E. and S.W. from Normandy, Brittany, and the Pyrenees towards the Apennines.

204. The geological dates of these several systems of elevation, determined, as will presently appear by the position of the strata on their flanks and at their bases, are as follows:—

- I. System of Vendée raised before the deposition of the Cumbrian group.
- II. System of Finistère raised between the Cumbrian and the green slate of Longmynd.

MAP OF MOUNTAIN SYSTEMS.

- III. System of Longmynd raised between the Longmynd slate and the Bala limestone.
- IV. System of Morbihan raised between Bala limestone and the Silurian deposit.
- V. System of Hunsrück raised between the Silurian and Devonian.
- VI. System of Ballons raised between the Devonian and carboniferous.
- VII. System of North of England raised between the carboniferous and Permian.
- VIII. System of Hainault raised between the Permian and Vosges sandstone.
- IX. System of Rhine raised between the Vosges sandstone and Triassic.
- X. System of Thuringerwald raised between the Triassic and Jurassic.
- XI. System of Côte d'Or raised between the Jurassic and lower cretaceous.
- XII. System of Monte Viso raised between the lower and upper Cretaceous.
- XIII. System of Pyrenees raised between the upper Cretaceous and lower Tertiary.



Fig. 117.—Map of France, showing the prevailing direction of the principal systems of mountains.

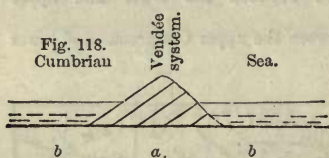
- XIV. System of Corsica raised between the lower and middle Tertiary.
- XV. System of Western Alps raised between the middle and upper Tertiary.
- XVI. System of principal Alps raised between the upper Tertiary and Diluvial.
- XVII. System of Tænarus raised between the Diluvial and Alluvial.

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205. We shall now briefly explain the stratigraphical characters by which these several dates have been ascertained.

I. SYSTEM OF VENDÉE.—In the earlier researches of M. Elie de Beaumont, the Hunsrück system, the elevation of which appeared to precede immediately the Silurian period, was assumed to be the earliest catastrophe of that kind of which the crust of the earth afforded any evidence. Observations more multiplied and exact, and a more elaborate discussion of the phenomena, discovered by his own labours and those of other geologists, have, however, conducted him to the conclusion that four of the existing mountain systems were produced at much earlier epochs.

The first of these, to which the French province of La Vendée



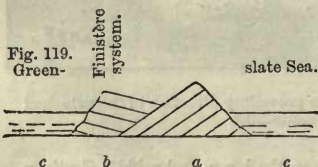
has given its name, is represented with the Cumbrian beds horizontal at its base, in the section fig. 118, where *a* represents the mountain range, and *b* the Cumbrian deposit.

We may therefore imagine *b* to be the sea of the epoch, which succeeded this elevation, in the bottom of which the Cumbrian formation was deposited. It is in this sense that the *Cumbrian sea* is to be understood, and a like form of expression will be used in a corresponding sense in other cases.

The date of the catastrophe by which the Vendée system was pushed up, must therefore be prior to the deposition of the Cumbrian strata.

This mountain system has hitherto been but little studied. Traces of it are shown by M. de Beaumont to exist in schists of Belle-Isle, of the embouchure of the river Villeine, in the mica-schists or gneiss on the banks of the river Blavet (dep. Morbihan), in Beaupréau, and Bourbon-Vendée.

206. II. SYSTEM OF FINISTÈRE.—By the catastrophe which



produced this system, the Cumbrian formation *b*, fig. 119, was uplifted, and in the period of tranquillity which followed, the waters deposited the strata of green slate of Longmynd in Wales. These last, *c*, are accordingly seen in horizontal

strata along the base of the system.

The date of the catastrophe is therefore posterior to the deposition of the Cumbrian formation, and anterior to that of the green slate of Longmynd and Westmoreland.

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Traces of this system exist in the gneiss and mica-schists of Brest, the Cumbrian schists between Pontivy and Falaise, the chloritic schists of Cherbourg, the Cumberland ranges, and at Gotheburg and Upsal in Sweden, whence it is continued into the southern part of Finland. It is also seen in the Pyrenees and in Catalonia.

207. III. SYSTEM OF LONGMYND.—The green slate deposits were forced up and inclined by this convulsion, and in the tranquil period which ensued, the Bala lime-stone beds, *d*, fig. 120, were deposited by the ocean on their flanks, where these strata are still seen in the same horizontal position.

The date of the catastrophe is therefore posterior to the lime-stone.

In Brittany the green slate does not appear between the Bala limestone *d* and the Cumbrian strata *b*, which shows that that part of Europe was dry land while the Bala sea was making its deposits.

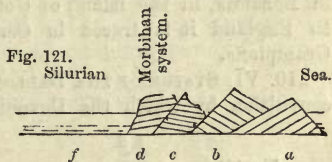
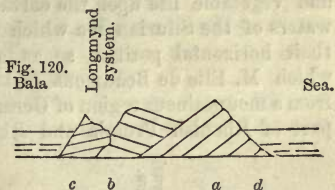
The stratification due to the Longmynd system has been traced in Limousin in France, in the mountains of Morocco, in the Serra da Estrella in Portugal, in the Erzgebirge in Saxony, in the gneiss mountains of Moravia, and of those parts of Bohemia bordering on Austria, on the north-east of the Wenner lake in Sweden, along the coast of the Gulf of Bothnia in Finland, and along that of Wiborg on the other side.

208. IV. SYSTEM OF MORBIHAN.—The convulsion which produced this system upheaved the Bala

formation *d*, fig. 121, throwing its strata, previously horizontal, into an inclined position. In the tranquil period which ensued, the mountains thus formed were washed by an ocean and seas in which were deposited the Silurian formation *f*, which is still horizontal, on the flanks of this system.

This convulsion, therefore, immediately preceded the Silurian period, and was posterior to the deposition of the Bala limestone.

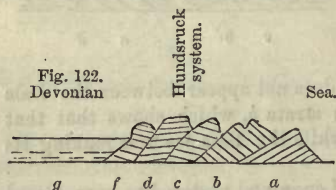
The system of Morbihan is very extensive; it is traced in the mica-schists and gneiss of the Loire Inférieure, in the islands which terminate the south-west coast of Brittany, in the granitic plateau which extends along that coast beyond Parthenay, and over part



of the Limousin, where traces of it appear between Tulle and Nontron. It is found also in the north-eastern part of Brittany and in the Bocage of Normandy. Traces of it are found in the mica-schists and gneiss of Messina, in the Erzgebirge, in Bohmerwaldgebirge, in the granitic steppes which extend from Volhynia towards the Don, in Labrador and in Canada.

209. V. SYSTEM OF HUNDSRUCK.—The catastrophe which produced this system coincided with the commencement of animal and vegetable life upon the earth. The strata deposited by the waters of the Silurian sea which preceded it, were uplifted from their horizontal position so as to form the mountain ranges to which M. Elie de Beaumont has given the name of *Hundsruck*, from a mountainous region of Germany extending over the southern part of Rhenish Prussia and Rhenish Bavaria, where it is connected with the chain of the

Vosges. Its geological date is fixed by the fact that the Devonian strata are found in a horizontal position upon its flank, as shown in fig. 122. The catastrophe must, therefore, have followed the Silurian, and preceded the Devonian period.

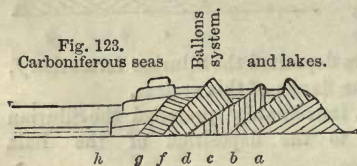


and preceded the Devonian period.

This system is traced through France, in Brittany, in the department of the Ille-et-Vilain, in the strata which cover Cape Finistère, in Mayenne, and in the department of the Orne and the Manche. It appears also in the slate formation of the Ardennes, of the Eifel, in the mountains of Hundsruck and the Taurus. It is also found in the Hartz mountains, in the Erzgebirge, in Bohemia, in the island of Gothland, in Finland and Lapland. In England it is traced in Cornwall, Westmoreland, and the Grampians.

210. VI. SYSTEM OF THE BALLONS.—This system originated in a convulsion by which the Devonian strata, *g*, were uplifted and

thrown into an inclined position, as shown in fig. 123. The waters of the globe, when tranquillity ensued, deposited the carboniferous beds in horizontal strata, *h*, in the



bottom of seas, oceans, and lakes, the latter being at more elevated levels than the former, as shown in the figure.

The date of the catastrophe is, therefore, antecedent to the carboniferous, and posterior to the Devonian period. This system is

traced in France in the anthracite schistous beds on the banks of the Loire and of the Brest canal. It is also seen in the department of Mayenne, in the south-east of Laval, in the southern part of the Vosges, in the chains of Lozère, Margeride, and the Corrèze.

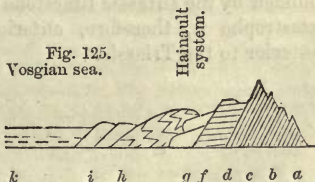
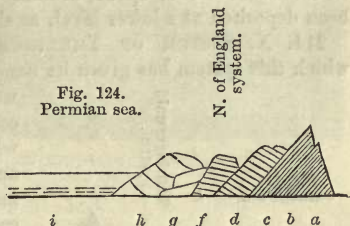
In England the system is directed from Cornwall to the Gramians, in Belgium from Avesnes to Liège, and in Germany in the Hartz mountains, which probably have received from it their peculiar form.

It may also be traced in Bohemia, Saxony, Sweden, Russia, Siberia, in the Altaï range, in North America, along the line of the Alleghanies, and in southern Asia.

211. VII. SYSTEM OF THE NORTH OF ENGLAND.—The convulsion which produced this system dislocated the coal formation, *h*, fig. 124, and in the tranquil period which succeeded the waters of the ocean deposited the Permian strata, *i*.

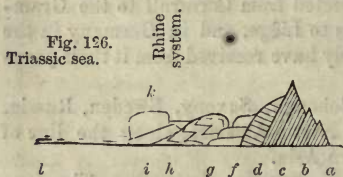
Its date, therefore, was prior to the Permian and subsequent to the carboniferous period. This system is characterised by lines of summit which extend from the parallel of Derby to the frontiers of Scotland, through Yorkshire, and between Cumberland and Northumberland. Traces of it are also found in the neighbourhood of Bristol, as well as in the south of Ireland. It is traced also both in Norway and Sweden, upon the crests of the southern chains.

212. VIII. SYSTEM OF HAINAULT.—The catastrophe which produced this system has been manifested less by any elevated ridges than by a series of dislocations and compressions which are seen in England, between Pembrokeshire and Mansfield, and which also traverse the Netherlands, running nearly east and west. All the existing strata, and particularly the coal measures, *h*, fig. 125, and the Permian strata, *i*, exhibit these effects. The strata of Vosgian sandstone are, however, undisturbed and horizontal as they were deposited from the waters, showing that the date of this catastrophe was anterior to their deposition and posterior to the Permian period. These positions of the Vosgian strata are apparent at Sarrebruck.



Traces of this system are found between Liege and Lille, in the direction of certain granitic islets, in the coal basin of Brittany, and from Laval towards Quimper.

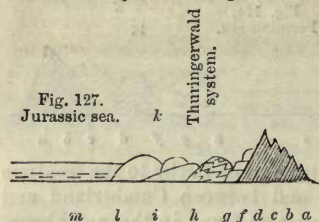
213. IX. SYSTEM OF THE RHINE.—This system is manifested chiefly upon the cliffs of the Rhine, between Bale and Mentz, with



various other parallel escarpments, indicating faults which have affected all the strata, including the Vosgian sandstone, *k*, fig. 126, patches of which they have pushed up to different heights, without

disturbing their horizontal position. Hence have resulted islands in the seas of this epoch, around which the Triassic group has been deposited at a lower level, as shown in fig. 126.

214. X. SYSTEM OF THURINGERWALD.—The mountains to which this system has given its name, and of which the Bœmherwaldgebirge is the continuation,



constitute the natural frontiers which divide Bavaria, Saxony, and Bohemia. The most remarkable effects of this catastrophe are manifested between Cassel and Linz, where the Triassic strata, *l*, are uplifted and overlaid by the

Jurassic deposits, *m*, in level strata, fig. 127.

Some traces of this system are seen in the south-western part of the Vosges, where the Triassic strata (*grès bigarré*) are raised considerably above the general level, an effect probably produced by the masses of serpentine which protrude in that region. Between Avallon and Autun some granitic islets and dislocated Triassic strata have also the north-west direction, and are surrounded by the Jurassic limestone in level strata. The date of the catastrophe is, therefore, anterior to the Jurassic period, but posterior to the Triassic.

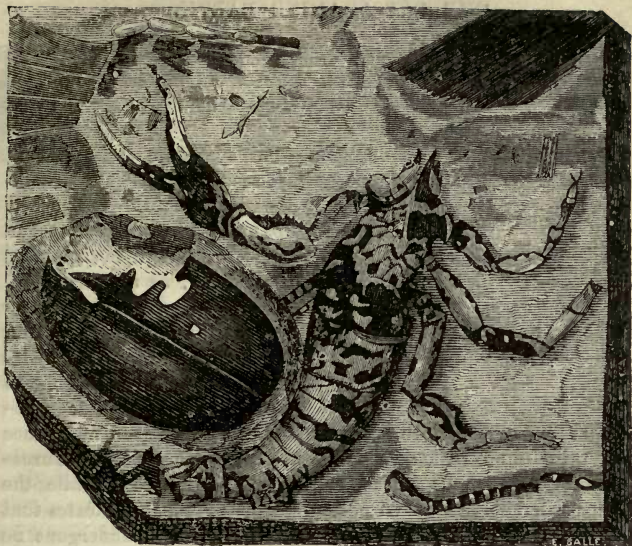


Fig. 143.—FOSSIL SCORPION (*CYCLOPHTHALMUS BUCKLANDII*).

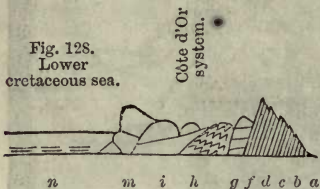
THE PRE-ADAMITE EARTH.

CHAPTER II.

215. Elie de Beaumont's mountain systems continued: System of Côte d'Or.—216. System of Monte Viso.—217. System of the Pyrenees.—218. System of Corsica.—219. System of the Western Alps.—220. System of the Principal Alps.—221. System of Tænarus.—222. Principal effects of this convulsion.—223. Extension of De Beaumont's system by analogy to the remainder of the globe; general plan of mountain systems.—224. Geological horizon explained; mineralogical characters insufficient to identify it.—225. Indications supplied by fossiliferous deposits.—226. Twenty-nine fossiliferous strata.—227. Zoological stratification.—228. Method of determining outlines of land and water twofold: mineralogical and zoological.—229. The mineralogical tests uncertain.—230. The zoological tests clear and definite.—231. Organic remains which characterise the bottom of deep seas.—232. Organic remains which determine the shores of seas.—233. Others which determine the bottoms of shallow seas.—234. Others which indicate the embouchures of rivers and estuaries.—235. Conventional terms.—236. Successive creations.—237. Geological periods and stages.—238. Six great formations.—239. Resolution of the earth's crust into 29 stages.—240. Six geological ages.—241. Succession of geological periods.—

242. Zoological terms: four principal divisions of animals.—243. Subordinate nomenclature.—244. Table of the classes of animals.—245. Zoological characters of the principal divisions.

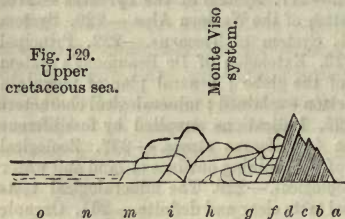
215. XI. SYSTEM OF CÔTE D'OR.—This system in its direction is nearly at right angles to the preceding, see fig. 116. The Jurassic deposits, *m*, fig. 128, are pushed up, and the lower cretaceous strata, *n*, ranged horizontally upon them, as shown in fig. 128. This system may be traced without interruption from Luxembourg to Roehelle, and in all the crests of the Jura. It was by this catastrophe



that the eastern border of the central plateau of France was raised and dislocated after the formation of the Jurassic group, which is there considerably elevated; while the other borders have suffered no derangement: which indicates that this plateau, in the chief part of its extent, has undergone no change since the Jurassic period. Traces of this catastrophe are also manifested in several other parts of France—north and south; in several parts of Germany; and especially in the Erzgebirge, which, though divested of the Jurassic limestone, has the lower cretaceous strata in horizontal beds at its foot.

The date of this catastrophe is, therefore, between the period of the deposition of the lower cretaceous strata and that of the Jurassic group.

216. XII. SYSTEM OF MONTE VISO.—The dislocation of the lower cretaceous deposits, *n*, fig. 129, by this catastrophe, and the



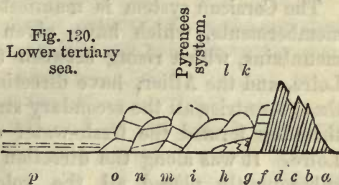
presence of the upper cretaceous deposits in their horizontal position, are distinctly manifested in the Alps of Dauphiné, showing that the date of the catastrophe is between the periods at which the upper and lower cretaceous deposits were made.

The upper cretaceous strata, represented by beds of nummulites, and sometimes, but very rarely, by grey and compact limestone, are alone found to be horizontal, as may be seen on the Col de Bayard and the Col Maurin. Indications of this system may also be traced at the south of Grenoble, in the north of Dauphiné,

in the mountains which connect the Alps with the Jura, as far as the Pont d'Ain and Lons-le-Saulnier. It was this catastrophe which determined the principal direction of the coasts of Italy, as well as that of a system of elevated ridges in Greece, of which Pindarus forms part.

217. XIII. SYSTEM OF THE PYRENEES.—By this catastrophe the upper cretaceous strata, *o*, fig. 130, were raised and dislocated.

The lower tertiary strata, *p*, being horizontal, show that the date of the catastrophe is between that of the lower tertiary and the



upper cretaceous periods. By this disturbance the upper cretaceous strata have been elevated to a considerable height, forming lofty cliffs, especially along the Spanish frontier.

The calcareous strata of the Paris basin, usually considered as the lowest of the tertiary strata, having but little extent over the surface of France, or even of Europe, it follows that at the epoch of the formation of the Pyrenean system, the chief part of the continent of Europe was suddenly raised above the waters and rendered dry land.

Not only the whole chain of the Pyrenees, as well in France as in the Asturias, belongs to this epoch, but also that of the Apennines, the Julian Alps, the Carpathians, the Balkans, and the mountains of Greece. The same direction is discovered in numerous dislocations and denudations in Germany, in the north of France, and in the Wealden of England; from whence it appears that this catastrophe must have had a vast extent, affecting certainly the entire surface of Europe and probably of the world.

218. XIV. SYSTEM OF CORSICA.—This catastrophe, unlike the former ones, is not marked by an elevation of the strata, which were formed under the water. After the preceding elevation, the Parisian lime-stone, which would then be found, is completely absent in those places where the new catastrophe was manifested.

The absence of this deposit signifies that the ground over the whole of Europe at that epoch was raised above the level of the sea; but as observation shows us that in this same place other marine deposits were made at a later period, it must be concluded that those parts which were first elevated above the ocean sunk below it at a subsequent period, so as to receive the superjacent deposits now found upon them. This must in fact have happened to part of the Paris basin, to Touraine, the chief part of Gascony,

all Switzerland, the valley of the Rhone from Lyons to the sea, as well as to several parts of Italy, Corsica, and Sardinia, which, not exhibiting any of the Parisian deposits, must have been brought above the level of the waters by the Pyrenean elevation, which produced the thirteenth system, and must have afterwards sunk to receive the subsequent deposits.

The Corsican system is manifested also by elevations and dismemberments, which have given their ultimate form to the mountains, which rising between the valleys of the Saone, the Loire, and the Allier, have directions from north to south. In these countries all the secondary strata are disturbed, and around them are formed the fresh-water deposits of Auvergne and the Loire. It was along the direction of this disturbance that were subsequently placed all the volcanic cones of the chain of the Puys.

Traces of this Corsican system are found in the mountains which connect the Alps with the Jura, in spite of the dismemberments which the succeeding catastrophes produced. There exists also a great number of chains having the same direction in the eastern and southern parts of Europe, in Tuscany, the Papal States, Istria, Albania, Greece, and so on. The islands of Corsica and Sardinia are also arranged from north to south, and present along the coast tertiary deposits in horizontal strata of the same age as those which are found in all the parts of France above mentioned.

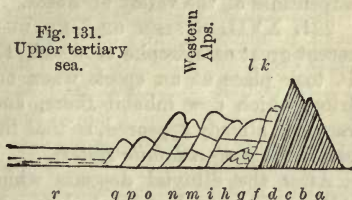
219. XV. SYSTEM OF WESTERN ALPS.—If the Swiss Alps and those of Savoy and Dauphiné present traces of catastrophes which took place since the elevation of the system of Côte d'Or, it is not less evident that the actual profile of the chain has a date much more recent. In fact the middle strata of the tertiary system, which were only raised above the waters after the date of the Corsican system, are now elevated sometimes to vast altitudes, as well as the Jurassic and cretaceous formations beneath them. The only strata found horizontal are the upper tertiary. Thus it follows that this chain of mountains, which includes the most lofty in Europe, were not raised to their present elevation from the common level of the continent until after the deposition of the middle tertiary strata.

The matter which broke through the crust of the earth in this catastrophe, was the particular species of granite of which Mont Blanc and Monte Rosa are formed. A multitude of granitic islands in different parts of the continent are also formed of it, on the flanks of which appear inclined the tertiary, cretaceous, and Jurassic strata. These granites at an early epoch in the progress of the science, when the principles which determine the

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dates of mountain ranges were less understood, being regarded as dating from the earliest geological periods, received the name of *Protogyne*. It is now known, however, that they did not break through the terrestrial crust until after the deposition of the middle tertiary system, seen in the strata around the Paris basin.

The relative position of the strata, determined by the elevation of the Western Alps, is illustrated in fig. 131, where the same letters are used to indicate the several strata, as in the former figures. The sea, which subsequently deposited in horizontal strata the upper tertiary system, is indicated in the figure.



This catastrophe produced not only the lofty chains of Savoy and Dauphiné, but extended its influence over Europe north and south. On the one side Nova Zembla and the whole Scandinavian Peninsula were affected by it, and on the other it produced a series of dislocations which are seen from Narbonne to Catalonia, determining the position of the whole Mediterranean coast of Spain. Its influence was felt south of the Mediterranean, producing the mountains of Morocco as well as those of the regency of Tunis.

220. XVI. SYSTEM OF PRINCIPAL ALPS.—This catastrophe has produced the grandest features of relief upon the European continent. The lacustrine deposits, formed after the elevation of the Western Alps, were themselves dislocated by it, and along the foot of the chain there are no other horizontal strata than the diluvial deposits of the present epoch. The matter pressed up from the inner regions of the globe by this catastrophe were the different varieties of melaphyres, the sienites, the euphotides and serpentines, which forced up all the tertiary deposits of Piedmont and Provence, as well as the granitic rocks which constitute the most elevated summits of the principal chains of the Alps.

Not only were all the mountains which extend from the Valais and St. Gothard into Austria raised on this occasion, but the greater part of the surface of Europe shared in the movement. In fact the surface of the continent was lifted into a gentle acclivity, directed towards the line of summit of this great chain. It is thus for example that the plains of Bavaria rise slowly in a direction a little east of south, and those of Lombardy in an opposite direction. In the south of France, in like manner, the tertiary formation rises from the south towards the north, from

the borders of the Mediterranean to Saint-Vallier, and on the other side the inclination is in the opposite direction. From the borders of the Loire the surface rises gently on the one side in the direction N.N.W., and on the other in the direction S.S.E., as far as the valleys of Auvergne. At the foot of the Pyrenees, the ophites, as well as the gypsums and the saliferous masses connected with them, form a tract whose direction is parallel to the chain of the principal Alps, and resemble the arrangement of the serpentines of the valley of Aosta.

221. XVII. SYSTEM OF TÆNARUS.—This is the last and most recent great catastrophe of which Europe has been the theatre. It took place at an epoch when our seas were peopled by the tribes which now inhabit them, and when possibly the human race had already appeared, so that the result might not inaptly be called the *post-Adamite system*.

After the diluvial deposits which surrounded the principal Alps in horizontal strata had been made, the surface of Tuscany underwent a dislocation parallel to a great circle, directed nearly N.W. and S.E. The deposits raised at this epoch include nothing but shells, similar to those of the existing seas, as may be shown by an examination of the tufa of the Phlegreæan fields, a district on the shore of the Bay of Baiæ, near Naples, and of the Somma of the island of Ischia. The sedimentary deposits of Sardinia, where M. de la Marmora discovered the remains of infant arts, appear also to have shared in this movement, which must therefore have been one of extremely modern date compared with all those already described.

222. It is to this catastrophe that must be ascribed the elevation of the Somma, of Stromboli, and of Etna, all of which would have been totally deranged if they had existed before the catastrophe of the principal Alps, by which so many ravages have been produced in all directions. To the same movement are probably also due the volcanic formation of Auvergne and the Vivarais, the ejections from which have issued from fractures and fissures produced by some of the antecedent catastrophes.

The system of elevation, the traces of which are seen in Provence, near Nice, in Sardinia, in Sicily, and in the Phlegreæan fields, is parallel to the modern system, which Messrs. Boblaye and Virlet have indicated at the southern part of the Morea, and which they have called *Tænarus*, from the adjacent cape of that name.

223. Such then, according to the remarkably able and perspicuous analysis of M. Elie de Beaumont, is the history of the principal changes which the surface of the globe has undergone

from the first consolidation of its external crust to the present epoch. Since it has been found in Europe (the only part of the world which has hitherto undergone sufficiently accurate geological survey), that the various ridges which have the same or parallel directions belong to the same epoch of elevation, analogy would justify a similar inference respecting all parts of the globe, and we should naturally conclude that parallel lines of direction and contemporaneity of formation are interchangeable principles. It is at least interesting to examine from this point of view the principal chains which are known in different parts of the earth.

To show how far the results of these observations in Europe may be generalised by such analogies, M. Elie de Beaumont designed for M. Beudant the plan which, by their permission, we have reproduced in fig. 132, showing the generalisation of the classification of mountain systems according to their dates, as above explained.

It will be seen upon this chart that the direction of the system of the Pyrenees extends from the Alleghanies in North America to the Indian Peninsula by the Carpathians, Mount Caucasus, the mountains of Persia, and the Ghauts in India. To the south of this line there are several parallel ridges, such as those which run from Cape Ortegal in the Asturias to Cape Creux in Catalonia. Also the little range of Grenada, the mountains which surround the southern side of the desert of Sahara, intersecting the direction of the Atlas, and, in fine, the Apennines, the Julian Alps, and the mountains of Croatia and Roumelia, extending to those of the Morea.

The system of the Ballons, so closely related in direction to that of the Pyrenees, is also represented in the Alleghanies.

The direction of the system of the Western Alps is observed from Morocco to New Zealand, passing along the eastern coast of Spain, the south of France, and a great part of the Scandinavian peninsula. Parallel ridges are found in the Cordilleras of Brazil, in the regency of Tunis, in Sicily, at the point of Italy, and in Asia Minor. All the littoral range of the old continent, from the northern cape of Lapland to Cape Blanco in Africa, partakes of this direction.

The direction of the principal Alps is in accordance with numerous other ridges. Chains parallel to this direction are found in the Atlas, in Spain, and across the old continent to the China Sea, including Mount Olympus, the Balkans, the Taurus, the central chain of the Caucasus between the Black Sea and the Caspian; in the long series of mountains which extend through Persia and Cabul, including the Parapamisan mountains in Afghanistan and eastern Persia, the range of the Hindoo Koosh,

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and, in fine, the Himalayas, which include the most lofty mountains in the world.

Parallel to the Corsican system are the chains of Syria and Palestine. Parallel to that of Monte Viso, those of Pindus. Parallel to the Thuringenwald are the mountains of Attica and Negropont. Parallel to the Côte d'Or, or perhaps the Hundsruock, are the Altaï range, and so on.

224. In all that has been hitherto explained the mineralogical components of the succession of strata are the only indications which have been given to determine each geological horizon,—a term to be understood as indicating that layer of the crust extending generally over the whole globe, which was contemporaneously deposited. If the waters of the oceans and seas of each epoch deposited everywhere a stratum composed of the same materials, and if the waters of no epoch anterior or posterior deposited like strata, then the mineralogical character of each stratum would supply certain indications of its date. But this has not been the case: on the contrary, strata which were incontestably deposited at the same epoch, are often composed in different places of different mineralogical constituents, while, on the other hand, strata of different epochs of deposition are sometimes found to consist of the same mineralogical components. Although, therefore, in a certain general sense, the mineralogical character of the strata, as has been explained, indicates the date of its deposition, yet when we come to define more exactly the successive geological horizons, these mineral characters cease to afford the necessary tests.

225. The indications which the mineralogical constituents of the strata have thus failed to supply, have happily been obtained from their fossiliferous deposits. From extensive observations, made both in the old and new world, it has been ascertained that in descending from stratum to stratum downwards, a succession of layers of organic remains have been found lodged within definite limits of geological level, the species found in each being almost totally distinct from those found in those above and below it. So that wherever we find the same organic remains, however different the strata in which they are lodged may be in their mineralogical character, we may conclude with certainty that they are of contemporaneous deposition.

226. Each fossiliferous stratum is distinguished from those above and below it, not only by the specific characters of its organic remains but also by its stratigraphic position, and, as we shall presently show, there are clear indications that the deposition of each such stratum, followed the destruction of the organic world by one of those violent convulsions which have been already described. Of these distinct fossiliferous strata twenty-nine

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have been enumerated and connected with indications of as many geological convulsions, the result of each of which was the complete destruction of animal and vegetable life upon the globe, the fossil deposits of the next strata of the series in ascending, being the remains of the animal and vegetable tribes which re-peopled and re-clothed the earth after the ensuing period of tranquillity.

227. The organic remains, deposited in the successive layers of the terrestrial crust, show the character of the animal and vegetable world during the periods of tranquillity which followed the several convulsions which thus devastated the globe. It is, however, a problem of not less high interest to determine the geographical character of the surface, as defined by the relative extent and outlines of land and water, during each of these periods. The solution of this problem would be attended with no difficulty, if we possessed a perfect knowledge of the condition of the sedimentary strata in all parts of the earth. But not to mention our want of all knowledge of the state of that large portion of the earth's surface, which is at present covered with water, we have as yet been able to effect only a very limited and imperfect survey even of that lesser part which forms the land. Nevertheless, the positive knowledge, small as it is, which the labours and researches of geologists have supplied, aided by obvious analogies on which conclusions are based, having, if not in all cases moral certainty, at least a high degree of probability, has afforded a close approximation to the series of geographical changes which that part of the earth, at present composing the land, has undergone since the earliest geological epochs.

228. The means whereby the outlines of land and water at any proposed geological period are determined are twofold, one method depending on the mineralogical character of the strata, and the other upon that of its organic deposits.

To explain these methods, let us suppose, for example, that it is required to determine the outlines of land and water, upon those parts of the globe of which we possess sufficient geological knowledge, during the Silurian epoch. The first point will be, in that case, to determine the extent and limits of that class of strata to which the name Silurian has been given. Let us imagine that all the strata of more modern date are removed, and the Silurian strata laid bare. These strata were deposited during the Silurian period at the bottom of the seas and oceans which then partially covered the globe, and whose outlines and limits are the immediate subject of inquiry. The land during this period consisted of those parts of the globe alone upon which the Silurian deposit was *not made*. If, therefore, we possess the means of discovering the exact extent and outline of the Silurian deposit, we possess

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all that is necessary for the solution of the proposed question. The outlines of this deposit are, in fact, identical with the outlines of land and water during the Silurian period. The land consisted, of course, of those strata which, being more ancient than the Silurian, were pushed above the level of the waters by the convulsion which preceded the period of tranquillity during which the Silurian strata were deposited.

229. If, therefore, the extent and limits of the Silurian deposit could be certainly and definitely ascertained, the problem would be solved ; but independently of the knowledge, more or less imperfect, which direct observation has supplied as to the extent and limits of this deposit, some uncertainty attends the identification of the various strata to which the name Silurian is properly given, by their mere mineralogical characters. It has been already explained, that strata of simultaneous deposition vary in their mineralogical characters from place to place, those which have been deposited in one part of the world consisting of mineral constituents wholly different from those which have been deposited at the same epoch elsewhere.

230. The doubt which this raises, however, has been removed by the light thrown upon geology by fossil zoology and botany. If the mineralogical characters of contemporaneous strata be doubtful, there can be no uncertainty as to the zoological character of their fossil contents.

Although it be true that many of the genera of animals and plants, deposited in strata of different dates are common, this is not the case with the species which, with very rare exceptions, are peculiar to each period. If, therefore, the observer, guided merely by the mineralogical character of the strata under examination, be uncertain as to its date, his doubts will disappear upon a due examination of its organic deposits. No other than the strata of one particular epoch can contain the same combination of species of animals and plants.

231. But the aid afforded by the organic deposits is not limited merely to the determination of the date of the strata. They also supply the means of determining, with much greater precision than can be obtained from the mere mineralogical constituents, the outlines of land and water. It is known that certain genera of animals can live only in the tranquil bottoms of deep seas ; there they live and there they die, and there their remains are buried in the strata deposited by such waters. Where such remains, therefore, are found in the strata of the crust of the earth, such strata must have been at the epoch of its deposition at the bottom of a deep sea or ocean.

232. The bodies of certain animals when dead and not dis-

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membered, will float upon water. The remains of such would necessarily be washed upon the shore, and cast upon the coasts between high and low water-mark. There, upon the successive returns of the tide, they would be gradually covered with sand or mud, and would thus be buried in the strata to become future fossils. Where such remains are found, therefore, the strata must have been upon the very limits of land and water, upon the strand or coast surrounding continents or islands. If the floating bodies of such animals be dismembered, either by incidental fracture or by the voracious attacks of other living animals, their dismembered parts being, bulk for bulk, heavier than water, would sink, and in such cases would be deposited at the bottom of the sea. It must, therefore, be expected that such dismembered remains would be sometimes found in the fossil state, in juxtaposition with the complete remains of animals which live exclusively in the bottoms of deep seas; and such, in fact, is found to be the case. But from these indications, rightly understood, no doubt can arise, since in no case is the entire body of such an animal found in such a position.

233. Other marine animals live not on the very coasts of the sea, nor yet in very deep waters, but frequent the littoral parts of seas and oceans, and in the bottom of these their remains are accordingly found.

Without going, with any degree of tedious minuteness, into the zoological characteristics of the several marine tribes, it will, therefore, be understood, that the deposition of the complete remains of certain species can only take place on the coasts of seas and oceans between high and low water-mark, the deposition of others on the littoral parts, and of others again in the bottoms of deep seas.

Thus, according to the varying zoological characteristics of the organic remains, the geologist is enabled to pronounce in a definite manner upon the outlines of land and water.

234. The bodies of dead animals and uprooted vegetables are carried by the currents of rivers to their embouchures, and are there deposited, mixed with certain species of marine animals. Thus, the combination of fresh-water shells, land animals, and plants, with the remains of marine animals, are the sure indications of the embouchures of rivers and estuaries.

235. Having explained the indications by which the outlines of sea and land and the animal and vegetable kingdoms corresponding to them at each epoch of geological time can be determined, with more or less approximation, we shall proceed to relate the history of the earth, from the first appearance of animated nature upon it to the present epoch. It will, however, be convenient

previously to fix the sense of certain conventional terms necessary to be used in such a narrative, by which the effects of the succession of terrestrial convulsions, and the intervals of geological time will be expressed.

236. As has been already stated, the earth we inhabit has undergone a long series of convulsions, affecting its entire surface, each of which has been succeeded by a long interval of tranquillity, during which, the waters, in a state of equilibrium and quiescence, deposited the solid matter suspended in them in a series of layers, and in each of these intervals the author of nature called into existence an animal and vegetable kingdom, resembling more or less the present.

237. The intervals of time which elapsed thus between convulsion and convulsion, we shall call *geological periods*, and the mineral strata deposited by the waters during such periods, we shall call *geological stages*.

Unlike historic, geological time is therefore not measured by years and centuries. Its units are much more vast. Each of them is a *period*, that is an interval of time, whose exact length is unascertained, but which must be considered as having an analogy, more or less close, to the interval which will have elapsed between the creation of the present animal kingdom and the epoch, whenever it may arrive, at which, it, like all those which pre-existed, shall be swept away.

238. An analysis of the strata composing the crust of the earth has presented certain features, upon which geologists have founded a classification of the stages just mentioned. According to this classification, the stages, from the igneous rocks to the latest deposits, which immediately preceded the appearance of the present state of things, have been resolved into six groups, denominated as follows:—

1. Azoic formation.
2. Palæozoic formation.
3. Triassic formation.
4. Jurassic formation.
5. Cretaceous formation.
6. Tertiary formation.

239. The Azoic formation consists of groups of strata, the lowest of which reposes upon the igneous rocks. The Palæozoic formation rests upon the uppermost strata of the Azoic group, and in it, as its name implies, are found the first traces of organic life. The general stratigraphic characters of the other groups may be seen by reference to the tabular sections of the Earth's Crust, given in § 47.

The Palæozoic formation consists of five distinct stages, each

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containing its own peculiar organic deposits. In like manner, the Triassic formation consists of two such stages, the Jurassic of ten, the Cretaceous of seven, and, in fine, the Tertiary of five; so that the whole fossiliferous portion of the earth's crust may be considered as consisting of twenty-nine stages, each stage being a catacomb in which the remains of the preceding creation are buried.

240. The intervals of time during which each of these six formations were deposited, we shall call *geological ages*. Thus, that in which the Azoic formation was deposited we shall call the *Azoic age*,^{*} that in which the Palæozoic formation was deposited we shall call the *Palæozoic age*, and so on.

241. The lesser intervals during which the several *stages* composing each geological *formation* were deposited, and during which, as already stated, an animated world was created, lived, and was destroyed, we shall call *geological periods*. Thus the Palæozoic *age* consisted of five *periods*, denominated in their numerical order, from the earliest or lowest to the latest or uppermost, the *first Palæozoic period*, the *second Palæozoic period*, and so on. In the same manner, the Triassic *age* consisted of two *periods*, the *first* and the *second*. The Jurassic of ten counted from the lowest, or most ancient, to the highest or most modern, and the like of the other formations.

242. Since it will be necessary to make frequent reference to the various forms of animal life, which from period to period prevailed upon the earth; and such references must occasionally necessitate the use of certain technical zoological terms, it will be convenient for those readers who are not already familiar with the elements of zoology, to give a general outline of the classification of animals which we shall adopt.

Naturalists have classed all the various forms of animal life into four primary divisions, denominated from their peculiar structure: 1. VERTEBRATA; 2. ANNULATA; 3. MOLLUSCA; and 4. RADIATA.*

243. Each of these primary divisions is resolved into a certain number of CLASSES; each class is again resolved into a certain number of ORDERS; each order is resolved into a certain number of GENERA;† each genus is resolved into a certain number of SPECIES, and each species consists of certain VARIETIES.

Here the classification terminates, the varieties being composed of individuals. Thus, if it be required to determine the zoological character of any individual animal, it is first necessary to state

* Much confusion prevails among the classifications adopted by naturalists; we shall, however, generally adhere to that of Cuvier.

† By an intermediate step, the orders are sometimes first grouped in *families*, and the families subdivided into *genera*.

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the *variety* to which it belongs, then the *species* of which this is a variety, then the *genus* of the species, then the *order* of the genus, then the *class* of the order, and, in fine, the great primary division to which this class belongs.

244. The four primary divisions above mentioned are resolved into classes, as follows:—The *Vertebrata* into *four*, the *Annulata* into *six*, the *Mollusca* into *five*, and the *Radiata* into *five*, making altogether twenty classes, as shown in the following table.

CLASSIFICATION OF ANIMALS.

CLASSES.		EXAMPLES.
VERTEBRATA.	Mammifers	Man, ass, dog, horse, whale.
	Birds	Eagle, sparrow, cock, ostrich, duck.
	Reptiles	Tortoise, lizard, snake, frog.
	Fishes	Perch, carp, eel, skate, shark.
ANNULATA.	Insects	Bee, grasshopper, flea, butterfly.
	Myriapods	Scelopendra, Iulus. Figs. 133, 134.
	Arachnides	Spider, scorpion, mite.
	Crustacea	Crab, lobster, shrimp.
	Cirrhipeds	Anatifa (animals which attach themselves to ships' bottoms.) Fig. 135.
	Annelides	Earth-worm, leech.
MOLLUSCA.	Cephalopods	Octopus, cuttle-fish, nautilus. Figs. 9,
	Gastropods	Snail, whelk. [10, 11, p. 62.
	Lamellibranchia (acephala).	Oyster, mussel.
	Brachiopods	Lingula, terebratula, pentamerus. Figs. 18, 19, p. 66.
	Bryozoa	Reticulipora. Figs. 20 to 23, p. 67.
RADIATA.	Echinodermata	Star-fish, sea-urchin. Fig. 136.
	Polyparia, or Zoophytes	Coral, astrea. Fig. 137.
	Foraminifera	Figs. 104, 105, 106.
	Amorphozoa	Sponges, fungi. Figs. 138, 139, 140.
	Infusoria	Fig. 107.

245. The Vertebrate division is characterised by an internal skeleton and a cerebro-spinal nervous system. It takes its name from the vertebral or spinal column, to which all the subordinate parts of the skeleton are attached.

The Annulata have no internal skeleton, but in its stead a tegumentary covering, composed of movable rings, which gives them their characteristic form. Their nervous system consists of two long cords running longitudinally through the abdomen, twisted at intervals into knots called *ganglions*. The tegumentary covering, which is always annular, is sometimes hard and calcareous, as in the lobster and shrimp, and sometimes soft, as in the earth-worm and leech.

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The Mollusca have neither internal skeleton nor articulated envelope. Their bodies are sometimes naked, but often protected by a shell.

The Radiata, including the lowest forms of organic life, is a group consisting of classes so heterogeneous, that many naturalists, not following Cuvier, have differently resolved them. They have in general no articulated skeleton, either internal or external, and scarcely exhibit the rudiments of a nervous system. Those to which the name Radiata is more properly applied are composed of organs disposed radially around a centre or axis.

Some naturalists have given to this division the name of ZOOPHYTES, from a Greek word, signifying the link between animals and vegetables; while others have confined this latter term to the Polyparia.



Fig. 182.—ILLUSTRATION OF THE ANIMAL AND VEGETABLE KINGDOMS DURING THE TERTIARY AGE.

a. *Palæotherium magnum*.
b. *Palæotherium minus*.

c. *Anoplotherium commune*.
d. *Crocodile*.

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CHAPTER III.

246. Derivations of the names.—247. Examples of the classes.—248. Number of fossil species.—249. Their distribution in 29 stages.—250. These stages correspond to 29 periods.—251. Successive manifestations of creative power.—252. First creation of organised beings.—253. General view of the series of catastrophes.—254. **The Palæozoic age**: Murchison's section of the corresponding stages.—255. How these are manifested in different parts of the world.—256. Stratigraphical evidence of the distinction of the stages.—257. Five stages of the Palæozoic formation.—258. Vegetable kingdom of the Palæozoic age.—259. **FIRST PALÆOZOIC PERIOD**.—260. Extent and limits of the seas.—261. Character of the Fauna.—262. Of the Flora.—263. Tropical climate universal.—264. No terrestrial animals.—265. Inhabitants of the seas.—266. Synopsis of the animal kingdom.—267. Examples.—268. Duration of this period.—269. **SECOND PALÆOZOIC PERIOD**.—270. Synopsis of the animal kingdom.—271. Genera created and revived.—272. General character of the animal and vegetable kingdoms.—273. Outlines of land and water.—274. Elie de Beaumont's Silurian map of Western Europe.—**THIRD PALÆOZOIC PERIOD**: 275. Mineral character of the strata.—276. Table of the Fauna.—277. Mollusca and Radiata.—278. Outlines of land and water.—279. Extent of the seas.—**FOURTH PALÆOZOIC PERIOD**: 280. Table of the fauna.—281. Fossil crustacea.—282. Mollusca and Radiata.

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246. SINCE the technical names of several of the classes into which the principal divisions are resolved will not be familiar to some of the readers of this tract, it may be useful to indicate the origins from which they are severally derived.

Mammifers is from a Latin word, signifying the bearers of breasts or paps, and consequently is applicable to animals which suckle their young.

Reptile comes from the Latin word *repto*, I creep or crawl.

Insects are so called from a Latin word, signifying the division of its body into segments.

Myriapods is a Greek word, signifying thousands of feet, figs. 133, 134.



Fig. 133.—The Scolopendra.—Example of the class Myriapods.

Arachnida is taken from a Greek word, (*ἀράχνη*, arachné,) signifying a spider's web.

Crustacea is taken from a Latin word (*crusta*), signifying a hard covering or crust.

Cirrhipeds, or Cirrhopods as it is sometimes written, take their

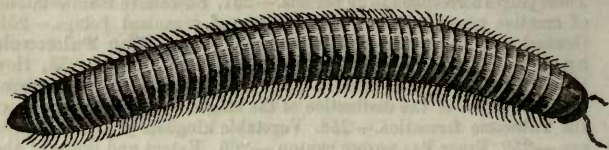


Fig. 134.—The Iulus. Example of the class Myriapods.

name from a Latin word (*cirrhus*), signifying hair, the compound signifying hair-footed animals; that is, whose members of locomotion are hairs, fig. 135.

Annelides, as well as Annulata, is taken from a Latin word (*annulus*), signifying a ring.

Cephalopods is a Greek compound, signifying *head-footed*, or animals whose organs of locomotion are upon their heads, figs. 9, 10, 11.

Gastropods is likewise a Greek compound, signifying *belly-*

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footed, or animals whose organs of locomotion are attached to their bellies.

Lamellibranchia is compounded of two Latin words, (*lamella*, a

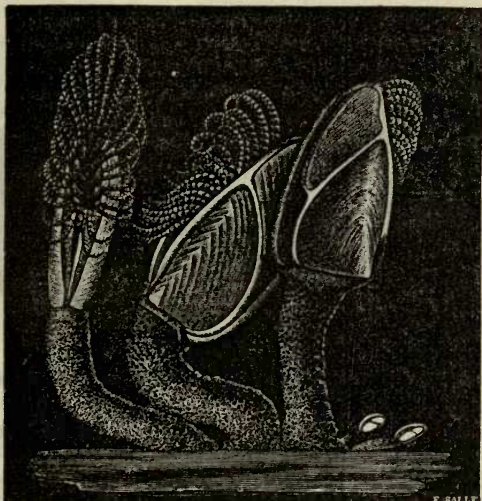


Fig. 135.—The Anatifa (animals which attach themselves to ships' bottoms).
Example of the class Cirrhipeds.

plate or *leaf*; and *branchia*, a *gill*;) the class including those animals which have gills or branchia placed by pairs along the body, of a lamellated form.

Acephala is also a Greek compound, signifying *absence of head*.

Brachiopods is a Greek compound, signifying *arm-footed*, or animals whose members of prehension are also those of locomotion, figs. 18, 19, § 71.

Bryozoa, from the Greek word *βρύον*, a mossy sea-weed, figs. 20 to 23, § 73.

Echinodermata is a Greek compound, signifying *spiny-skinned*, fig. 136.

Polyparia is another Greek compound, signifying produced by polypes or corals, fig. 137.

Foraminifera is a Latin compound, implying the existence of foramina, or openings in the partitions of the shells, figs. 100 to 106.

Amorphozoa is a Greek compound, signifying living things *destitute of definite form*, figs. 138, 139, 140.

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Infusoria is a Latin name, implying the existence of this class of animals in vegetable and other infusions, fig. 107.

247. Since many of the names of the genera and species of animals and plants would be unintelligible to a large portion of

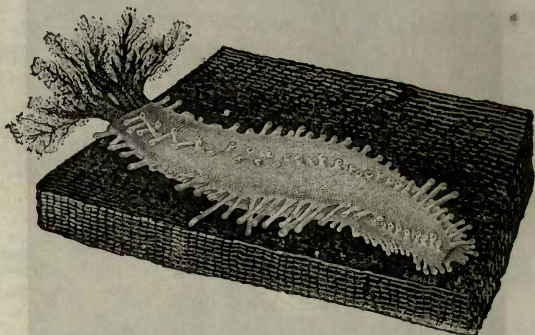


Fig. 136.—The Holothuria. Example of the class Echinodermata.

our readers, while a full explanation of them would be incompatible with the objects and limits of the present tract, we shall generally adopt the expedient of giving a specific example of each

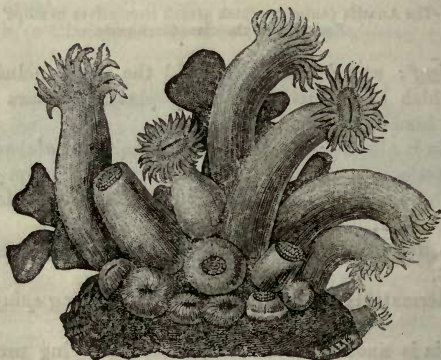


Fig. 137.—Polypes of the genus Asteroides. Example of the class Polyparia.

in a parenthesis after its technical name. In many cases, however, even this mode of illustration is not possible, since none of the species or genera of certain orders are familiar objects, and in many cases those which we shall have to mention have ceased to

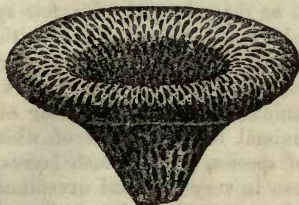
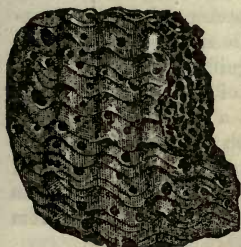
CLASSIFICATION OF ANIMALS.

exist, so that no analogous example can be found among the living classes. In such cases we shall endeavour, as often as convenient, to accompany the technical name with a figured

Fig. 138.

Fig. 139.

Fig. 140.



Examples of Amorphozoa.

Fig. 138.—*Cliona Duvernoyi* (fossil).^a

Fig. 139.—*Cribrospongia reticulata*.

Fig. 140.—A part magnified.

representation of some species of the object. In the preceding table we have accordingly given some familiar examples, and we now annex figured illustrations of those objects which may be supposed to be the least familiar to ordinary readers. The references to the figures are given in the table.*

248. Geologists have ascertained the existence of the organic remains of about twenty-four thousand species of the different orders of animals, which they have assigned to upwards of fourteen hundred and seventy genera. Of these numerous species none survive; but we find in the existing animal kingdom about five hundred and fifty of the genera, the remainder being extinct.

249. Until very recently, it was considered by geologists that those twenty-four thousand fossil species were distributed through the strata of the crust of the earth, in such a manner that the great majority of them should be common to strata of very different dates of deposition, and that comparatively few were exclusively found in strata of a particular date; these few being consequently called *characteristic species*, inasmuch as they supplied to geologists certain tests, by which the dates of strata left uncertain from their mineralogical character could be fixed. The elaborate researches of M. D'Orbigny, who has catalogued,

* We must warn the reader that he must not understand that the example given in the parenthesis is in every case an individual of the species, or even of the genus, of the object to be illustrated. It will be more generally a specimen of the class or order. This is the only expedient that I can devise to popularise this part of our subject.

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described, and located on the earth's crust, above eighteen thousand species of Mollusca and Radiata alone, have demonstrated that all the species found in strata of the same date, with extremely rare exceptions, are characteristic of these strata, being found there exclusively, and in no other strata of anterior or posterior deposition; so that, instead of a few species only being characteristic, it would appear that all the species are so, with exceptions so rare as to be altogether insignificant.

It appears, therefore, that on the crust of the earth there is a sort of organic stratification, consisting of a series of superposed layers of animal remains, each of which contains a distinct collection of species, no two such layers having any species in common, save in very rare and exceptional cases, and that even these exceptions may be satisfactorily explained as arising from accidental causes.

250. Since twenty-nine such organic stages have been determined, it must be inferred that during the geological period corresponding to each of them, the earth was peopled by a collection of animals which had no previous or subsequent existence, and which constituted a distinct and independent creation. This inference is fully confirmed by the fact, that on comparing stage with stage, we do not find the successive faunas passing one into the other by slow and imperceptible degrees; but, on the contrary, we find between those of every two successive stages, a distinct and unmistakeable line of separation. In the superior layers of each stage, the fauna peculiar to it totally disappears, as though it were annihilated by some universally destructive agency; and it is not until we arrive at the lowest or first layer of the succeeding stage, that the next fauna appears not gradually and successively, but suddenly and simultaneously over the whole extent of the globe, so far as geological observation has extended, and everywhere, from the equator to the poles, the same species are found in it.

251. Hereupon two questions necessarily arise: What are the physical causes which produced the total destruction of the fauna of the inferior stage, and the creation of that of the superior? To the former a satisfactory answer is obtained, as we shall presently show, by the geological convulsions, the devastating effects of which have been already frequently noticed in these pages. But when we seek the agency which, twenty-nine times successively called into existence a new animal kingdom to replace that which was previously destroyed, we are compelled to acknowledge the limits of our intellectual powers, and to prostrate ourselves in reverence before that Omnipotence to whose agency alone these great creative acts can be assigned. There are limits which the human

DESTRUCTION AND CREATION.

mind cannot overleap, circumstances before which the march of intellectual research must be arrested, and ultimate facts which must be admitted without any human power of explaining them.

252. When the temperature of the earth had cooled down to a point compatible with the maintenance of organised life, and its crust had thickened so as to give it comparative stability and permanence, it pleased the Omnipotent to call into existence the animal and vegetable kingdom, that continued to live upon the earth during the Cambrian period, and was destroyed by the convulsion which closed that period, the remains of the species composing it being deposited in its strata.

253. After this complete destruction of animal and vegetable life a period of repose ensued, after which the same Almighty Power at the commencement of the second Palæozoic or Silurian period, called into existence another and different animal kingdom; different, at least, so far as regarded species, many of the genera being common to that of the previous period. The close of the Silurian period was signalised by a like catastrophe, this second animal kingdom being similarly swept away and the earth again left unpeopled and destitute of vegetation. Another period of repose ensued, after which, at the commencement of the third Palæozoic or Devonian period, a third animal and vegetable kingdom was called into existence, and continued upon the earth during the Devonian period, at the close of which, in like manner, another destruction ensued, followed by another creation at the commencement of the fourth Palæozoic or Carboniferous period, and so on destruction following destruction, and creation following creation, during all the succeeding periods to that which immediately preceded the human epoch. The latest or fifth Tertiary period terminated like the others in a convulsion which swept from the earth all animal and vegetable life existing upon it, burying the remains in the highest layers of its crust. After a final period of repose, the present animal kingdom, including the human race, were called into existence, and the world as we see it commenced.

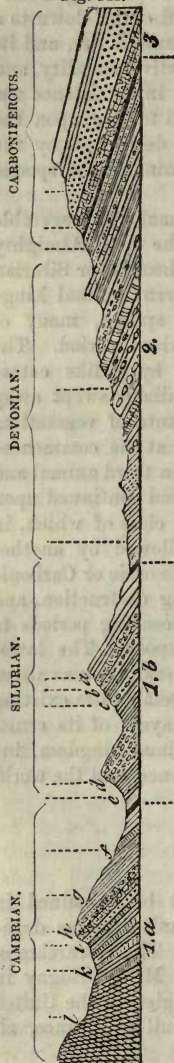
The Palæozoic Age.

254. The Palæozoic formation, whether it be examined in reference to its mineralogical strata or the organic remains deposited in it, is resolved into five distinct stages. The researches of Murchison in England and Russia, those of M. D'Orbigny in South America, those of several eminent geologists in the United States, and the observations of M. de Verneuil in France, all concur in establishing this division.

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The stratification from the superior limit of the Azoic rocks upon which the Palæozoic formation rests, to the upper limit

Fig. 141.



of the Carboniferous stage, delineated in section by Sir R. Murchison, is shown in fig. 141, as it is presented on the surface of the earth in strata variously inclined. The five divisions into which the whole formation is resolved are denominated, proceeding from the lowest upwards, the Cambrian (sometimes called the Lower Silurian), the Silurian, the Devonian, the Carboniferous, and the Permian.

255. In the geological map of England by Sir R. Murchison, the stages succeed each other regularly throughout Wales and the western parts of England, where they appear in some places in concordant, and in others in discordant, stratification. They are traced scarcely less distinctly in Germany. The same regular succession of five superposed stages is seen in Russia and in Sweden from west to east, and extending in the same order to Central Russia. Along the slopes of the Ural, the stages being tilted upwards, are found, as may be expected, in a contrary order, the lowest being the most eastward, and the uppermost the most westward. M. D'Orbigny found the same regularity in South America.

256. The complete distinction of the stages, and the geological evidence of the convulsions by which they were rendered separate and independent, are found in the fact that in some places particular stages are absent. Thus we see in the United States the three first stages only existing in concordant stratification for hundreds of leagues, the lowest being absent. The same is observable in the department of Sarthe and the Manche in France. Elsewhere the Carboniferous and Devonian stages alone are found; as, for example, in the Pas de Calais, and in certain parts of Spain, or one only of them, as in Norway, Sweden, Russia, France, and some other countries.

257. Upon a general view of the Palæozoic formation and its component stages, there is evidence, founded on the indications which

FIRST PALÆOZOIC PERIOD.

have been already explained, that during each of the five successive periods the earth consisted, as at present, of continents and seas; that the continents were clothed with vegetation; that the seas were peopled by various marine tribes, some living at parts of great depth, some near the coasts, and others upon the shores between high and low water-mark; and that even the crust of the earth was subject to the same gradual oscillations which are observed to exist at present in the north of Europe and in other parts of the globe.

258. The existence of a vegetable kingdom in each of the five Palæozoic periods is proved by the presence of coal in all the stages. That mineral is worked in Portugal in the Silurian stage. In Spain its richest mines are in the Devonian stage, and in Saxony it is worked in the Permian stage. These facts show, that though the coal-fields are by far most prevalent in the Carboniferous, the other Palæozoic stages furnish their share of that mineral to industry and the arts.

Having thus taken a general view of the Palæozoic age, considering its periods collectively, we shall now briefly notice the most remarkable circumstances attending these periods severally.

FIRST PALÆOZOIC PERIOD.

259. The first Palæozoic stage includes the group of strata of which the Cambrian system of Sedgwick and the lower Silurian system of Murchison are composed. It appears from an examination of the strata, more especially those observed in North and South America and Bohemia, that a considerable time must have elapsed between the epoch at which this stage began to be deposited on the subjacent Azoic rocks, and the commencement of the animalisation of the globe. Strata of immense thickness are everywhere found between the superior surface of the Azoic rocks and the first layers of organic remains, the formation of which, according to all the known laws of sedimentary deposits, must have occupied a great lapse of time. That these were deposited from waters which had a temperature too elevated to allow of organic life, is in the highest degree probable; and it must be inferred that the creation of an animal and vegetable kingdom, or a fauna and flora, as they are called, was postponed until the temperature of the globe had fallen to a point not much above that of the present tropics.

260. During this first Palæozoic or Cambrian period the waters of the ocean covered all that part of Europe extending from Spain to the Ural mountains, as well as a great part of North and South America. The shores of these seas can be traced, by the

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means already explained, in the strata of England, Sweden, and Russia, and in those of the State of New York. The organic deposits show that, like the present seas, they were inhabited by the various classes of marine animals which are peculiar, some to shores within the play of the tides, others to littoral regions more removed, and others to the great depths of the ocean.

261. The only Vertebrate animals of this period which have left their traces are some placoid fishes, which belong to the family of Cestracions, of which the shark presents a living example. Of articulated animals there lived a great number of Trilobites (fig. 6, § 62), an order which at a period a little later became extinct. The forms of life, however, which most abounded belonged to the Molluscous and Radiated divisions. Tentaculiferous cephalopods swarmed in the seas, the genera of some of which did not survive the period, and those of many disappeared before the close of the Palæozoic age.

Molluscous brachiopods, marine gastropods, lamellibranchia (oyster and mussel), and bryozoa, existed in numbers more or less considerable.

Of the Radiata there prevailed echinodermata, asteroids, and numerous crinoids, a great number of polyparia or zoophytes, and some amorphozoa.

262. The remains of vegetation consist chiefly of some marine plants peculiar to the State of New York, described and figured by Mr. Hall. Coal of this epoch, which can only consist of vegetable remains, is worked at Vallongo in Portugal.

The remains of vegetation, as well as the visual organs of animals, show that light and air existed then as now. We have already noticed the structure of the eyes of Trilobites, and shown their analogy to those of insects and other Annulata.

263. It is certain, that not only at this first period, but at all succeeding periods, until that which immediately preceded the present creation, the heat proceeding from the interior predominated over the influence of solar radiation, in a sufficient degree to efface all isothermal lines, and to equalise the climate at all latitudes from the equator to the poles. Proofs of this will appear in the analysis of the fauna and flora of all the stages, since the same tropical genera and families will be found deposited in the strata at the line and within the polar circle, as well as at all intermediate latitudes.

264. In this first period no terrestrial animals existed, although the land was clothed with a luxurious vegetation; at least no remains of such are found. The perishable nature of the insects, and many other Annulata, might have caused their disappearance; but, notwithstanding this, traces of such tribes are found in later

FIRST PALÆOZOIC PERIOD.

deposits, and it is probable that if land Vertebrates had existed, remains of them would be found.

265. The seas, however, abounded with life, including animals of all the principal divisions, Vertebrata, Annulata, Mollusca, and Radiata.

In the following table we have given the genera of the animal kingdom during this period, exclusive of the Annulata.

266. *Synopsis of the Animal Kingdom (exclusive of the Annulata) in the First Palæozoic Period.*

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	0	0	0	0	0
	Fishes	1	1			
MOLUSCA.	Cephalopods . .	12	12	0	2	2
	Gastropods . .	12	12	0	0	0
	Lamellibranchia .	11	11	0	1	1
	Brachiopods . .	14	14	0	4	4
	Bryozoa	8	8	0	3	3
RADIATA.	Echinodermata .	11	11	0	5	5
	Polyparia . . .	7	7	0	3	3
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	2	2	0	1	1
		78	78	0	19	19

267. Eighteen genera of Trilobites existed in the first Palæozoic period, of which seven never re-appeared in any future period, and are consequently characteristic of the Cambrian stage. Some individual examples of other Annulata have been found, one of the most remarkable of which is the *Nereites Cambriensis*, fig. 5, § 36. The number of species of the Mollusca and Radiata alone, exclusive of the other divisions, which are ascertained to have lived in this period, is 426. These have been catalogued and described by M. d'Orbigny.*

268. The duration of this first world of animal and vegetable life may be estimated with some degree of approximation by the thickness of the deposits produced in its seas, which has been found in many places so much as 13000 feet.

Its close is marked by the discordances of stratification which prevail between the Cambrian and the Silurian strata, and it is probable that the convulsion by which it was terminated, was that which raised the Morbihan system of mountains of M. Elie de Beaumont (208).

* *Prodrome de Paléontologie*, vol. i. p. 1—26.

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SECOND PALÆOZOIC PERIOD.

269. The convulsion which closed the preceding period was succeeded by an interval of tranquillity of greater or less duration; after which, it pleased the Omnipotent, by a second great act of creation, to clothe the land with vegetation, and re-people the earth.

270. In the following table we have given, as in the former case, a synopsis of the generic forms of this new creation.

Synopsis of the Animal Kingdom (exclusive of the Annulata) in the Second Palæozoic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	8	7	1	0	0
MOLLUSCA.	Cephalopods . .	11	2	9	3	0
	Gastropods . . .	10	2	8	0	0
	Lamellibranchia .	8	2	6	0	0
	Brachiopods . .	17	7	10	1	0
	Bryozoa	10	5	5	1	1
RADIATA.	Echinodermata .	15	12	3	8	6
	Polyparia	20	16	4	3	3
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	1	0	1	0	0
		100	53	47	16	10

As before, the only important traces of the Annulata of this period which remain, are the Trilobites, of which nineteen genera have been found. Of these, eleven are identical with genera which existed in the previous period, and eight are new.

The total number of species of Mollusca and Radiata which have been ascertained to have existed in this period is 418, which have been described and catalogued.*

271. The only class of Vertebrates yet created were fishes, of which eight genera existed in this period, all of the placoid family (shark). One of these had existed in the previous period, the other seven being new.

272. The remains of the vegetation consist of some genera of marine plants, found in the state of New York, and figured by Mr. Hall. That the continents generally were covered with vegetation is proved by the traces of coal found in this stage at St. Sauveur.

As in the former period, the animal remains are analogous to

* Prodrôme, p. 27—35.

THIRD PALÆOZOIC PERIOD.

those of the tropics at present, and were uniformly distributed over all latitudes to which geological observations have been extended, from the line to latitude 69° , from which it is inferred, that during this period the temperature of the earth was everywhere tropical, and everywhere uniform.

273. The outlines of land and water were not materially different from those of the first period. It is probable, however, that the seas retired from a portion of the central part of Brittany, and advanced eastward, as well in Wales as in Cumberland, leaving in the west a larger portion of uncovered land. They extended, probably without interruption, from Europe to America, covered a great part of North and South America, as well as all that part of Europe which extended from Spain to the line of direction now occupied by the Ural mountains.

274. An examination of the Silurian strata has enabled M. Elie de Beaumont to trace an approximate sketch of the outlines of land and water in Western Europe, from which the map given in fig. 142 was drawn.

It appears from this, that there existed at this time two granitic tracts, one between Brest and St. Malo, and the other between Brest and Poitiers; the former having the direction of the Finistère, and the latter of the Morbihan system, a neck of land connecting them having the direction of the Longmynd system. These probably, therefore, owed their elevation to the three convulsions which produced these ranges severally. Other tracts of land existed in Cornwall, in Scotland, and in Sweden, as shown in the map, having the direction of the systems of Finistère and Longmynd. The granitic plateaux which include the Limousin and Auvergne were also then above the waters, and were connected with a much larger tract, extending from Toulon to Innspruck. This second Palæozoic period appears to have been terminated by the effects of the geological disruption which produced the Hundsruok system of M. Elie de Beaumont (209).

THIRD PALÆOZOIC PERIOD.

275. After an interval of tranquillity as before—the land being divided from the waters—the earth was repopled with new tribes and clothed with new vegetation. The strata deposited during this third palæozoic period have been denominated by Sir R. Murchison, Devonian, from the circumstance of their prevalence in that county. The principal mineralogical characteristic of the Devonian stage is the old red sandstone.

276. The animal world, now called into life, consisted, so far as

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appears by its organic remains of 156 genera (exclusive of the Annulata), of which 75 were new and 81 revived, having existed in the former periods. It appears from the following table that in this period the vertebrate animals were still limited to fishes, but their number was considerably increased, having consisted of only 8 genera in the preceding period, and of 26 in the present. This period was also signalised by the first appearance of reptiles, of which, however, one genus only, called the *Sauropterus*, was

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Third Palæozoic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	1	0	0	0
	Fishes	26	26	0	13	13
MOLLUSCA.	Cephalopods . . .	13	5	8	6	2
	Gastropods	22	9	13	1	0
	Lamellibranchia .	18	7	11	0	0
	Brachiopods . . .	20	3	17	4	2
	Bryozoa	10	4	6	3	2
RADIATA.	Echinodermata . .	18	11	7	23	8
	Polyparia	26	8	18	10	5
	Foraminifera . . .	0	0	0	0	0
	Amorphozoa . . .	2	1	1	0	0
		156	75	81	59	32

created, being a large marine animal. Among the Annulata some genera of Tubicolous Annelidans appeared—so called from having lived in tubes. Among the crustacea as before, were some genera of Trilobites, but the period took its prominent character from the vast numbers of cephalopods, gastropods, lamellibranchia, brachiopods, crinoids, and polyparia, which swarmed in the seas.

277. The total number of species of mollusca and radiata alone, which existed in this period, as ascertained by the organic remains deposited in the stage, was 1198. These have been catalogued and described.*

The seas nourished marine plants, the discovery of many of which is due to Mr. Hall, of the United States. The continents were covered with a luxuriant vegetation, as appears from the rich deposits of coal found in the great basin of Sabero in Spain, which were long considered to have belonged to the succeeding period. The uniformity of temperature over the whole surface of

* Prodrôme d'Orbigny, 52—109.

FOURTH PALÆOZOIC PERIOD.

the globe, is proved by the existence of the same animal and vegetable remains in this stage, in all localities to which geological researches have been extended.

278. The configuration of land and water in this period has been determined on the principles already explained. The Hunds-ruck system of Elie de Beaumont, directed W. 31° S., having raised up the Silurian stage, increased the magnitude of the islands which existed in the previous period, created new ones, and gave to their coast its own prevailing direction. This will appear by reference to the map (fig. 144) sketched by M. Elie de Beaumont, showing the probable outlines of land and sea in Western Europe in the succeeding period. A tract of land arose above the waters on the west of Frankfort, and another on the S.W. of Strasbourg, which was united with the former continent. The central plateau of France was extended to the Pyrenees. The space included between the two islands of Brittany, which previously existed, was now filled up, and being united with the land round Cherbourg formed one continuous tract, which was connected on the one side with the southern part of England, and on the other with the Limousin by Poitiers. The land constituting the Scandinavian peninsula was also considerably increased. Upon several parts of this tract the Silurian deposits have never been since disturbed.

279. The seas of this period covered Asia Minor, Spain, Belgium, Germany, and Russia, as far as the Ural chain. The land which now forms the shores of the Frozen Ocean was also covered by these seas. In the east they extended from Asia Minor to China; in South America they covered all the tropical regions of Peru, Bolivia, and Brazil, and probably extended as far as the Falkland Islands, as is proved by the organic deposits found in all these regions. In North America they covered all the land which extends from Alabama to the state of New York. They also covered New Holland and Van Diemen's Land. Thus it appears that the Devonian sea extended in the Southern Hemisphere to 52° of latitude, and in the northern to the polar circle.

FOURTH PALÆOZOIC PERIOD.

280. The convulsion which terminated the previous period destroyed 59 generic animal forms, which never again reappeared upon the earth, as well as 1198 species of Mollusca and Radiata, besides all the species of the other classes. After an interval of tranquillity the earth was again repopled, and once more clothed with rich vegetation. The new animal kingdom called into

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existence is shown in the following table, exclusive as before of the Annulata.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fourth Palæozoic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	1	0	1	1
	Fishes	46	33	13	37	27
MOLLUSCA.	Cephalopods . .	11	3	8	6	2
	Gastropods . . .	26	6	20	6	1
	Lamellibranchia	19	4	15	4	1
	Brachiopods . .	13	0	13	2	0
	Bryozoa	14	6	8	5	5
RADIATA.	Echinodermata .	18	11	7	17	10
	Polyparia	20	6	14	19	6
	Foraminifera . .	1	1	0	1	1
	Amorphozoa . .	1	0	1	0	0
		170	71	99	98	54

281. It appears that of former genera 99 were revived, while 71 new ones were created, making the total number of genera then existing on the earth 170. Besides these, however, there were at least 3 genera of Crustacea. This period was also signalised by the first unequivocal appearance of insects and Arachnida (scorpions) (fig. 143), the organic remains including besides Arachnida three orders of insects—the Coleoptera (beetles), the Orthoptera (crickets, locusts, grasshoppers), and the Neuroptera (dragon-flies).

282. Exclusive of the remains of animals of the other divisions, the number of species of Mollusca and Radiata alone ascertained to exist in this period, is 1047, which have been catalogued and described by M. D'Orbigny.*

* Prodrôme, p. 110—162.



Fig. 142.—Configuration and relative extent of land and water in Western Europe during the Silurian period.*

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CHAPTER IV.

283. Outlines of land and water.—284. The vegetable kingdom.—285. Coal deposits.—286. Convulsions which terminated the period.—
FIFTH PALÆOZOIC PERIOD: 287. Composition of the strata—288. Destruction of the fauna and flora of preceding period.—289. The new animal kingdom.—290. Outlines of land and water.—291.

The dark parts are supposed to represent land. This map is reproduced, with the permission of the author and publisher, from the *Traité de Géologie* of M. Beudant.

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Changes of the continents.—292. Character of the fauna.—293. Absence of land animals—uniformity of climate.—294. Geological convulsions.—RETROSPECT AND RECAPITULATION OF THE PALÆOZOIC AGE : 295. Commencement of animalisation.—296. Prevailing forms.—297. Trilobites.—298. Characteristics of the carboniferous stage.—299. Carbonised vegetables.—300. Fossil vegetable species.—301. Their prevailing characters.—302. Contrasted with the present vegetable kingdom in the same localities.—303. Radiata of the carboniferous period.—304. Crustacea and insects.—305. Fossil scorpions.—306. Fishes of the carboniferous period.—307. Fossil fishes discovered by M. Agassiz. **Triassic Age.**—308. Triassic formation lies over the Palæozoic.—309. Geographical configuration—Map of France in Triassic age.—310. Vegetation. **FIRST TRIASSIC PERIOD :** 311. Outlines of land and water—character of animal kingdom.—312. Chelonian reptiles (tortoises).—313. Foot-tracks of birds.—314. Synopsis of animal kingdom. **SECOND TRIASSIC PERIOD :** 315. Mineral character of this stage—animal genera created and revived.—316. Outlines of land and water—animal kingdom.—317. Generic synopsis.

283. THE convulsions which produced M. Elie de Beaumont's system of the Ballons, pushed up certain parts of the Devonian stage, modifying the outlines of land and water, and augmenting the extent of the land. The map (fig. 144) represents approximately the seas and lakes of this period as they existed in Western Europe.

284. Arborescent ferns, with their beautiful lace-like foliage; slender *Lepidodendrons*, fig. 145; *Lycopodiaceæ* (club-mosses), with leaves as varied and beautiful as the ferns; and gigantic *Sigillaria*, emulating the magnitude of the Conifers, abounded.

Assuredly no scenery upon the earth at present can convey an adequate idea of vegetation so luxuriant. Some of the mountainous regions of the torrid zone may convey a faint notion of it; but at the period to which we now refer, this magnificent flora covered the whole surface of the land from the tropics to Melville Island, now the regions of eternal frost.

285. By a dispensation of Providence, which cannot fail to excite sentiments of admiration and gratitude, this luxuriant vegetation of a remote epoch of the earth, flourishing countless ages before the creation of the human race, was destined to become for that race one of the most powerful agents of industry and civilisation. Buried in the earth by a long series of geological convulsions, it was submitted to the process of carbonisation, and converted into those vast beds of mineral combustible which now supply the materials out of which art and science have educes not only the means of artificial light and heat, but also a mechanical agent whose influence upon the condition of mankind is incalculable. To these precious deposits of the carboniferous

FORMATION OF COAL.

period are, in short, due the physical agencies by which the art of gas illumination, all the industries depending on the production



Fig. 144.—Map of Western Europe in the Carboniferous period, sketched by M. Elie de Beaumont.*

of artificial heat, and all the wonders effected by the steam-engine are due.

286. It is to the close of this fourth Palæozoic or Carboniferous period, and before the commencement of the Permian deposits,

* This map is reproduced from the *Geology of M. Beudant*, with the permission of the author and publisher.

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that Sir R. Murchison assigns the date of the disruption of the earth's crust, which produced the Ural chain of mountains.

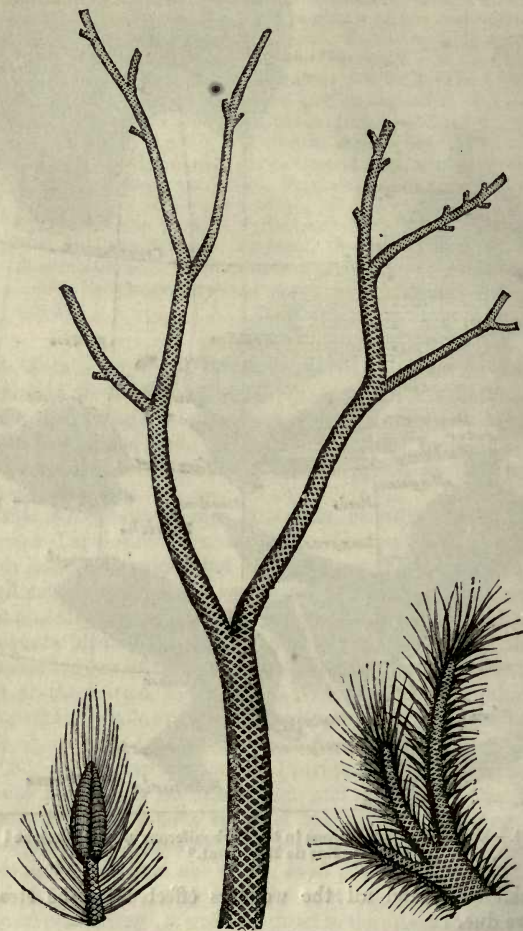


Fig. 145.—*Lepidodendron Sternbergii*.

M. Elie de Beaumont assigns to the same epoch the convulsions which produced the system which he has designated that of the North of England (211), the prevailing direction of which is

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N. 5° W., and S. 5° E. M. d'Orbigny assigns to the same epoch the convulsion which produced the Chiquitean system of mountains in Bolivian Peru; and to the disturbance produced by one or all of these simultaneous convulsions, may be ascribed the destruction of the whole animal and vegetable kingdom which closed this fourth Palæozoic period.

FIFTH PALÆOZOIC PERIOD.

287. The strata which, in the regular series lie over the Carboniferous stage, have received the name of the Permian, from the Russian province of Perm, on the confines of Europe and Asia, which is traversed by the Ural mountains, this being the region in which the geological characteristics of this stage were first studied and determined by Sir R. Murchison. The component strata are commonly known to geologists as those of the magnesian limestone and new red sandstone, in contradistinction to the old red sandstone of the third Palæozoic or Devonian stage. That this stage has been separated from the carboniferous by a geological convulsion is rendered manifest by the discordance of the stratification in some places, and by the isolation of the stages in others, the Permian stage being found in some places without the Carboniferous under it, showing that it was there deposited in parts of the earth's surface which were dry land during the Carboniferous period.

288. The convulsion which terminated the Carboniferous period buried beneath its ruins nearly a hundred genera which never again appeared. Of the Mollusca and Radiata alone, exclusive of the other classes, 1047 species were destroyed by this catastrophe. All the vast forests which covered the extensive tracts of land were similarly buried, and form, as already explained, the coal-fields now found in the Carboniferous strata. This catastrophe was probably followed, as in the former case, by a period of tranquillity, during which a suspension of all animal and vegetable life took place. The seas, meanwhile, returning into their beds, the land was again divided from the waters, and the outlines of the new continents and islands became defined. The earth being thus gradually prepared, Omnipotence once more exerted its creative power, re-peopled the world, and clothed the land with vegetation.

289. The new animal kingdom, as far as its remains inform us, consisted of eleven new, and forty-five revived genera, making a total of fifty-six. Two of these belonged to the class of reptiles, twelve to that of fishes, and the remainder to the inferior divisions of the animal kingdom, as shown in the following

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synoptical table—exclusive, however, of the Annulata, whose numbers cannot be so certainly ascertained.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fifth Palæozoic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	{ Mammifers . . .	0	0	0	0	0
	{ Birds	0	0	0	0	0
	{ Reptiles	2	1	1	1	1
	{ Fishes	12	5	7	6	3
MOLLUSCA.	{ Cephalopods . .	2	0	2	0	0
	{ Gastropods . . .	5	0	5	1	0
	{ Lamellibranchia	13	3	10	0	0
	{ Brachiopods . .	11	0	11	3	0
	{ Bryozoa	8	1	7	4	1
RADIATA.	{ Echinodermata .	1	0	1	0	0
	{ Polyparia . . .	2	1	1	2	1
	{ Foraminifera . .	0	0	0	0	0
	{ Amorphozoa . .	0	0	0	0	0
		56	11	45	17	6

290. The seas during this period covered most probably the space occupied by the chain of the Vosges mountains in Europe, extending in a direction nearly N.N.E., through Rhenish Bavaria and the Grand Duchy of Baden, into Saxony and Silesia. The identity of the species of organic remains found in these deposits in Silesia, England, and Russia, proves that the seas of this period which covered the central part of England, from Glamorganshire to Durham; communicated with those of Russia, where they extended in the direction N.N.W. between the Ural chain and Novogorod, from the 48° of latitude to the Frozen Ocean.

They also covered Tasmania, in the Southern Ocean; and probably, therefore, extended over the entire surface of the earth from the 43° of south to the 80° of north latitude.

In the western part of continental Europe the outlines of land and water did not undergo any remarkable change. The great central plateau of France formed a large island, which extended to the south as far as the Pyrenees, as is indicated by the terrestrial plants now found in the deposits of Lodève, in the department of Herault, in France. The remainder of continental Europe consisted chiefly of a tract of land in Brittany. In England, besides parts of Devonshire and Wales, which were previously raised above the level of the ocean, a vast island was formed, extending N. 5° W. and S. 5° E., consisting of land forced

RETROSPECT OF PALÆOZOIC AGE.

above the Carboniferous seas, and surrounded east and west by the waters of the Permian seas.

291. The Ural chain was also further heaved upwards, so as to form the series of mountains which now exist. In South America the continents were also considerably increased in extent in the west. The Chiquitean chain extended over some hundred leagues, from Brazil to the eastern extremity of the Andes. South America appears then to have had the form of a vast triangle, the length of which, from north to south, extended over 35° of latitude.

While the land underwent but little change in France, it was enlarged both in England and Russia, towards the east, by a considerable portion of the Carboniferous stage not covered by the waters of the Permian sea.

292. The fauna of this period were almost exclusively marine, a few, perhaps, being fluviatile. The two genera of reptiles were both fluviatile and marine. The fishes belonged to the Placoid and Ganoid families, of which the shark and sturgeon are living examples. Among the Mollusca, certain species of oysters first appeared in this period.

293. Although the organic remains present no traces of land animals, it is nevertheless probable that they prevailed upon the continents at least as extensively as in the previous period. M. Brongniart considers the vegetable fossils of this period to hold an intermediate place between those of the previous and succeeding periods. The marine fauna found in the Old and New World from the line to the 80° of latitude being identical in its character, demonstrates that central heat still neutralised the effects of solar radiation, so as to efface all isothermal lines, and that over the entire globe a tropical climate prevailed.

294. This period, like the others, was tormented by geological convulsions, of which the traces are found in the discordance of the stratification and the increased elevation of the immense surface constituting the Permian formation in Russia, in the dislocation which produced the Netherland range of mountains and those of South Wales. The effects of these geological perturbations are altogether in accordance with the superior limits of the fauna and flora of the Permian stage.

RETROSPECT AND RECAPITULATION OF THE PALÆOZOIC AGE.

295. With the Permian period was closed the Palæozoic age. The first assemblage of animated beings which peopled the earth included types of all the principal divisions of animal forms, but those of the lowest class most abounded. Thus, three animal and vege-

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table kingdoms were called successively into existence, permitted successively to live, and were destroyed successively before any vertebrate animals superior to fishes existed, and even these were limited to the Placoid and Ganoid orders. No land animals had yet appeared. Reptiles made their first appearance in the fourth period, where they were represented, however, only by a single genus; and even in the fifth and last period, no more than two genera existed, one of which had been revived from the preceding period. During the entire age, not more than sixty-seven genera of fishes existed, and two of reptiles. Of the superior orders of birds and mammifers none were yet created.

296. The animal forms which most abounded were those of Tentaculiferous Cephalopods, Marine Gastropods, and Lamelli-branchia, Brachiopods, Bryozoa, Echinodermata, and Polyparia, commonly known as zoophytes. Of the divisions of Annulata in this age but little is known, owing, no doubt, to the perishable nature of their structure. One family, however, of Crustacea, Trilobites, appeared during the first and succeeding periods in such numbers, as to confer upon the epochs a distinct organic character. These fossils have been long known in England under the local and erroneous name of *Dudley insects* or *locusts*, from their having been found in that district in such immense numbers. This remarkable family of Crustaceans did not survive the fourth Palæozoic or Carboniferous period, their principal development being in the Silurian and Devonian periods, which literally teemed with them. These crustaceans have no existing type, that which most resembles them being the Bopyrus, a small parasitical animal which attaches itself to the prawn, causing a large swelling in its body.

297. The fossil trilobites are generally from one to six inches in length, attaining, nevertheless, in exceptional cases to two feet. They were protected by a crustaceous shell or case, composed of annular segments, jointed one upon the other like those of the lobster's tail. This testaceous covering seems to have had a contractile power like that of the armadillo, since the animal is sometimes found more or less expanded, and sometimes coiled up. Owing to the absence of all traces of antennæ or feet, it is supposed that these animals adhered to rocks like fuci, or collected together in masses, forming conglomerations. Some naturalists, however, assume that they had locomotive power in water, either by soft paddles which have disappeared, or by skulling forward by means of the flexible extremity of their bodies. From the peculiar structure of the mouth it has been inferred that they were carnivorous, preying on naked mollusca or annulata, with which their remains are sometimes associated.

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The curious and interesting structure of the eyes of the trilobite have been already noticed (62).

298. The most striking and imposing feature of the fourth or Carboniferous period of the Palæozoic age, consists in the numerous accumulations of vegetable remains which are presented in the coal deposits in all parts of the world. As the science of Comparative Anatomy has enabled the geologist to reproduce the forms and determine the habits and functions of the animal tribes which peopled the earth at these remote periods—in like manner the principles of Botanical Science have enabled him, basing his conclusion upon the visible structure of vegetable remains found in the coal beds, to reproduce, as it were, the vast forests of palms and arborescent ferns, the groves of conifers, and all the exuberant vegetation which flourished during the second, third, and fourth Palæozoic periods.

299. The layers of pure coal consist altogether of carbonised vegetables; and when it is considered that these strata are sometimes sixty feet in thickness, it seems difficult to explain how an accumulation of wood, plants, and foliage could ever be produced in such enormous quantity. Though the vegetable remains are always in a carbonised state, the leaves often possess such tenacity as to be separable from the stone. These and the seed-vessels which are found in iron-stone, have in many cases undergone metallic impregnation, which has in no degree impaired the delicacy of their structure. The coal plants have been determined to the number of nearly a thousand species, two-thirds of which are related to the ferns and the higher tribes of Cryptogamia, the remainder consisting of conifers and some flowering monocotyledonous (having only one seed lobe), and dicotyledonous (having two seed lobes) trees; numerous species, however, are still undescribed, and new forms are continually discovered.

300. More than two hundred species of plants have been discovered in the British coal-mines, but far greater numbers are found in the Carboniferous deposits of Europe, America, Australia, and even Greenland; and it is worthy of note, that in the coal-field on the shores of Lake Breton, fossil plants have been discovered identical with those found in the coal-mines of Northumberland, though these deposits have been made in opposite sides of the earth.

301. The prominent character of the vegetable kingdom during the Carboniferous period was the immense predominance of the vascular and higher tribes of Cryptogamic plants, with which were associated in a much less number, palms, conifers, cicadeæ, and other plants approaching to the character of Cactææ and Euphorbiacææ. Plants analogous to the tribes of Ductulosæ

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abounded, differing, however, both in genera and species from those which at present exist. Thus fossil Calamites, related to the equisetum or mare's-tail, are found, which measure eighteen inches in circumference and thirty or forty feet in height, while the recent analogous species seldom exceed an inch in diameter and two feet in height. The fossil arborescent ferns called *Sigillaria*, measure sometimes fifty feet in height, having their summits covered with a splendid canopy of foliage. The foliage of the herbaceous species is extremely elegant, presenting endless varieties in their forms and in the skeletons of their leaves. The fossil arborescent club-mosses, called *Lepidodendra* (from a Greek compound signifying scaly tree), attain frequently an elevation of from sixty to seventy feet. Some of these trees have been found entire from their roots to their topmost branches. Their foliage consisted of simple linear leaves, spirally arranged round the stem. These leaves, in many cases, had been shed from the tree, the marks of their points of attachment never having been obliterated. In their external forms, the mode of ramification and the disposition of their foliage, they closely resemble the existing *Lycopodiaceæ*, or club-mosses. Notwithstanding the enormous disparity of magnitude between these latter and the fossil *Lepidodendra*, Brongniart has shown that both belong to the same family. The fossils were in fact nothing more than arborescent *Lycopodiaceæ*, analogous in magnitude to the largest existing pines, and forming extensive forests during the Carboniferous period, beneath whose shade flourished the lesser ferns and associated plants now found with them in the same coal strata.

302. The contrast which such a flora presents with that afforded by the woods and forests which now grow on the surface of the carboniferous districts of England is as striking as the discrepancy between the zoology of the Palæozoic formation and that of the present day.

303. Among the Radiata of the Carboniferous period are enormous quantities of corals denominated, according to their several forms, tubipora, syringopora, catanepora, &c. Of the Echinodermata, crinoids swarmed in such infinite numbers that entire strata are composed of their petrified remains. These species have also received names indicative of their forms, such as *actinocrinus*, *cyathocrinus*, and so on.

Among the shells of the Carboniferous period are found innumerable Foraminifera, which are detected in slices of Yorkshire limestone with the microscope. The upper strata of the mountain limestone of the lower Volga in Russia consist of masses of a minute species of fusulina, resembling grains of wheat. Entire

RETROSPECT OF PALÆOZOIC AGE.

beds of mountain limestone or conglomerates are formed of shells of Brachiopods, such as spirifers, leptænæ, &c.

304. The Crustacea and Insects of the Carboniferous period have been less accurately ascertained than the other divisions of the animal kingdom. A few species of the fluviatile crustaceans, the Cyprides, are found in the coal deposits. Small crustaceans are also found in the iron-stone, which are referable to the *limulus* or king-crab, a genus which abounds in the seas of India and America. Dr. Mantell found in the iron-stone of Colebrook Dale several fossil beetles resembling the *curculio* or diamond beetle; he also discovered the wing of a large neuropterous insect closely resembling a species of the living *Corydalis* of Carolina.

305. With the insects imbedded in the coal strata are found the remains of those animals, to which they served as food. The fossil scorpion (fig. 143) already mentioned is an example of this. This fossil, which measures about two and a half inches in length, is embedded in coal-shale, with leaves and fruit; the legs, claws, jaws and teeth, skin, hair, and even a portion of the trachea, or breathing apparatus, are severally preserved. It had twelve eyes, the sockets of which remain. One of the small eyes and the left large eye retain their forms, and have the cornea or outer skin preserved in a corrugated or shrivelled state. The hairy covering of the animal is also preserved, being neither carbonised nor decomposed; the substance of which it consists, electrine, has resisted decomposition and mineralisation.

306. Among the fishes which lived during the Carboniferous period, and which, as already stated, are exclusively of the Placoid and Ganoid families, some genera are worthy of note.

Of the Sauroid fishes, two genera, one called the *Megalichthys*, is covered with enamelled smooth quadrangular scales, very thick, and nearly an inch wide. The head is protected by strong armour of enamelled plates. The teeth are large striated hollow cones. This fish was from three to four feet in length.

Another called the *Holoptychius*, attained in some instances the length of thirty feet. The scales were thin and circular, varying from one to five inches in diameter. The head is surrounded with a sort of shagreen helmet, having a surface irregularly ridged. It has large teeth of great density, some conical and others long and slender.

307. M. Agassiz has discovered about a hundred species of fossil fishes of the Devonian and third Palæozoic period, of which the most remarkable are the *Cephalaspis*, *Pterichthys*, and *Coccosteus*.

The *Cephalaspis*—a Greek compound, signifying buckler-head—received its name from the head being protected by a buckler or shield. The plates which cover it are united in a single osseous

case. The body is covered with scales, those of the head being highly ornamented.

The *Pterichthys* takes its name from two wings or lateral appendages, which, like the spines of the common bull-head, were weapons of defence. The head and fore part of the body are protected by large angular escutcheons—two eyes are placed in front of the lateral spines. The species of these which occur in the British strata are from eight to ten inches in length, but specimens of still greater length were found in Russia by Sir R. Murchison.

Triassic Age.

308. Above the Palæozoic formation a group of strata has been deposited, called the Triassic formation (47), consisting of the new red sandstone, muschelkalk, and variegated marls, or marnes irisées of the French. This formation has been generally considered as consisting of three stages. A scrupulous analysis of its composition, as well with relation to its fossils as to the conditions of its stratification, shows that, between the sandstone and the muschelkalk, there is no real distinction either geological or zoological. We shall, therefore, here, following D'Orbigny, consider the Triassic formation as consisting of two stages only; the first, or lower, called the Conchiferous; and the second, or upper, the Saliferous, from the prevalence of salt-mines in it; such, for example, as those of Salins, Lons-le-Saulnier, and Salzbourg.

309. The configuration of the land in this, as in the former age, is traced by observing the outlines of the strata, and the distinction of their organic remains. The convulsion which elevated the system of the Rhine (213) produced a general deluge, which devastated the earth, destroying altogether the vegetation which clothed it, and the races which peopled it in the last period of the preceding age. When the seas had retired to their new beds, and tranquillity was re-established, the outlines of land and water were defined. A great island seems then to have extended from the west of England across France to Austria, including Brittany, the Limousin, and Forez, throwing out two peninsulas, one towards the Pyrenees, and the other across the province of Burgundy (fig. 146).

Another island coincided in position with Belgium, throwing out a peninsula to the south, which extended over the Vosges and the Grand Duchy of Baden, its direction being parallel to the range of the Black Forest. The land previously uncovered in England, extending from Cornwall through Wales to Cumberland, was probably increased by a large surface, extending from Derbyshire to Durham. With these exceptions, the land seems to have remained generally as it was in the Carboniferous and Permian

FIRST TRIASSIC PERIOD.

periods. Since the Permian stage in Russia is not overlaid by the Triassic, it follows that the Swedo-Russian continent, at the commencement of the Triassic age, extended over all northern Russia, from the Baltic to the Ural Mountains, and from the shores of the Frozen Ocean to the government of Saratov.

310. A great change was produced in the character of the vegetation compared with that of the former periods. The arborescent ferns and tall equisetacean trees which prevailed in such lavish profusion in the latter periods of the Palæozoic

age, now existed in greatly diminished numbers, while the conifers and plants, analogous to the zamias and the cycadææ, figs. 147, 148, formed an important feature of the flora, preluding the immense development which these classes underwent in the succeeding periods.

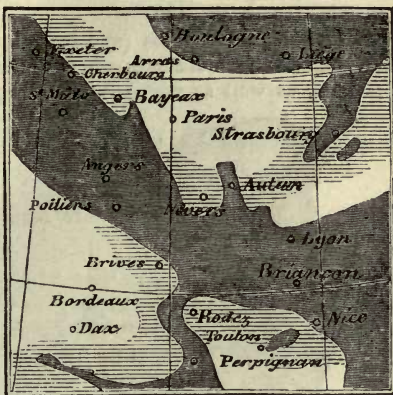


Fig. 146.—Map of France in the Triassic age.

FIRST TRIASSIC PERIOD.

311. By the catastrophe which terminated the Palæozoic age, ninety-one species of Mollusca and Radiata, besides all the existing species of the superior classes, were destroyed, never to re-appear upon the earth. Seventeen generic forms also became extinct. When tranquillity was re-established, and land and water again became fitted for the maintenance of organised life, Almighty Power called into existence thirty-six new generic animal forms, and revived thirty-three, which formerly lived, making a total number of sixty-nine genera in the new animal kingdom. Independently of the species of the higher classes of animals, not so exactly ascertained, the genera of Mollusca and Radiata alone consisted of 107 species,* which have been catalogued and described.

The marine littoral and fluviatile deposits have supplied the means of tracing the shores of the seas of this period, and prove them to have been subject to the same atmospheric and tidal influences as those which affect the seas and oceans of the present

* "Prodrome d'Orbigny," vol. i. pp. 171—178.

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epoch. Among the remains of this period are eleven genera of saurian reptiles, of most singular forms, among which are included the Labyrinthodon, the restoration of which by Professor Owen is given in fig. 109.

312. Chelonian reptiles (tortoises) now appeared for the first time, together with six new genera of Ganoid fishes. Crustaceous decapods, as well as acetabuliferous cephalopods (fig. 149), also

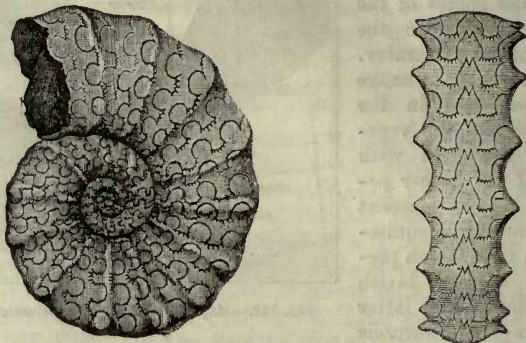


Fig. 149.—*Ceratites nodosus* (Fossil).

appeared for the first time, besides numerous lamellibranchia and echinoderms.

The Chelonians of this period are only known by the traces of their footsteps, which remain upon the rocks, figs. 108, 150.



Fig. 150.—Foot-print of the *Chirotherium*, a chelonian, or tortoise.

313. Numerous birds probably existed in this period; but, like

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the chelonians, they have only left traces of their foot-prints (fig. 110). In fig. 151, are the imprints of the three fore phalanges of a



Fig. 151.—Foot-prints and marks of Rain-drops.

bird, accompanied by the curious incidental impressions of rain-drops which happened to fall at the moment the bird passed the spot.

314. *Synopsis of the Animal Kingdom (exclusive of the Annulata) during the First Triassic Period.*

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Charac- teristic.
VERTE- BRATA.	Mammifers . . .	0	0	0	0	0
	Birds	?	?	?	?	?
	Reptiles	14	13	1	10	9
	Fishes	13	6	7	7	4
MOLLUSCA.	Cephalopods . .	2	2	1	0	0
	Gastropods . . .	9	2	7	0	0
	Lamellibranchia	17	5	12	0	0
	Brachiopods . .	3	0	3	0	0
	Bryozoa	2	1	1	1	0
RADIATA.	Echinodermata .	6	5	1	2	2
	Polyparia . . .	1	1	0	0	0
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	1	1	0	0	0
		69	36	33	20	15

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SECOND TRIASSIC PERIOD.

315. The mineral character of this stage has been variously denominated, red marl, keuper sandstone, and variegated marls.

The effects of the perturbation which closed the Conchiferous period are visible in the discordances of stratification, as well as by the marked distinction between the fauna and flora.

The termination of the Conchiferous period was marked by the destruction of all the existing species, animal and vegetable, of which there were 107 species of Mollusca and Radiata alone. With that period twenty genera ceased to exist (314). The next act of creation was signalised by the appearance of thirty-five new generic forms, and the revival of fifty-nine, which previously existed.

316. The outlines of land and water continued to be nearly the same, but the seas were peopled with tribes different from those of the preceding period. Three new genera of reptiles, all of which were probably fluviatile, appeared. The seas possessed two new genera of fishes and ammonites, and various other Mollusca were now first called into existence, giving a special character to the new fauna, which, with that of the first Triassic period, seems to constitute a transition system from the Palæozoic to the Jurassic age.

No remains of the terrestrial animals of this period have been found; but the land was certainly clothed with a luxuriant vegetation, of which numerous species have been preserved, as already mentioned, figs. 146, 147.

317. *Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Second Triassic Period.*

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	4	3	1	4	3
	Fishes	6	2	4	1	0
MOLLUSCA.	Cephalopods . .	8	1	7	5	0
	Gastropods . . .	20	4	16	2	0
	Lamellibranchia	22	5	17	1	0
	Brachiopods . .	7	0	7	4	0
	Bryozoa	1	0	1	0	0
RADIATA.	Echinodermata .	4	2	2	1	0
	Polyparia . . .	12	11	1	2	2
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	10	7	3	1	0
		94	35	59	21	5



Fig. 147.—*Zamia pungens*.



Fig. 148.—*Cycas revoluta*.

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CHAPTER V.

318. Convulsion which closed the age. **Jurassic Age.**—319. Division of Jurassic formations into ten stages by M. D'Orbigny.—320. Nomenclature and thickness of the stages.—321. Section of the strata from the Vosges towards Paris.—322. State of the earth in the Jurassic age.—323. Jurassic age zoologically distinguished from the Triassic.—324. Distribution of the species into ten stages.—325. General inference respecting the distribution of specific forms.—326. Geography of Europe in Jurassic age—D'Orbigny's map.—327. The Anglo-Parisian basin.—328. The Pyrenean basin.—329. The Mediterranean basin.—330. Variation of the shores of these seas from period to period.—331. Discordances and isolation of the strata.—332. Corresponding observations on the organic deposits—333. Variations of the outlines of land during this age.—334. Change of condition of land between Toulon and Innspruck.—335. Accurate knowledge of the Jurassic geography.—336. Elie de Beaumont's Jurassic map.—337. *Ichthyosaurus*, *Plesiosaurus*, and *Pterodactyle*.—338. Other animals of the Jurassic age.—339. Coral reefs.—340. Insects.—341. The vegetable kingdom. **FIRST JURASSIC PERIOD.** 342. Convulsion that closed the Triassic age.—343. First Jurassic stage determined by discordances and isolation of stratification.—344. Extent of the seas in Western Europe—remarkable discordances of stratification on the Alps.—345. Synopsis of the animal kingdom.—346. Reptiles, fishes and insects.—347. Convulsion which closed the period. **SECOND JURASSIC PERIOD.** 348. Mineral character of this stage.—349. Synopsis of animal kingdom.—350. Marine fauna.—351. No traces of terrestrial fauna.—352. Vegetation of the period.

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318. THE close of the Triassic age is identified with the convulsion to which M. Elie de Beaumont ascribes the elevation of the Thuringerwald system of mountains, including the Bohmerwald-Gebirge, and the Morven ranges, the prevailing direction of which is W. 40° N. and E. 40° S. M. D'Orbigny assigns to the same date and cause the increased elevation of all the eastern part of the Andes, included between the 5° and 20° lat. S., and having the direction W. 50° N. and E. 50° S. By combining with these dislocations the numerous discordances of stratification which are observed, we shall find causes abundantly adequate to the explanation of the total and sudden disappearance of the flora and fauna of the Triassic age, to give place to the new creations of the succeeding one.

The Jurassic Age.

319. Upon the Triassic formation the Jurassic has been deposited, and is therefore the result of the next geological age. Many divisions of the strata composing this great formation have been proposed, some based upon the mineralogical characters of the strata, derived, however, in general, from observations more or less local, and others from an imperfect generalisation of prevailing fossils. We shall here adopt the analysis of this formation proposed by M. D'Orbigny. "After many years of laborious observation," says that eminent palæontologist, "during which we have only advanced from confirmation to confirmation, without encountering any inconsistent facts, we have arrived at the conclusion that the Jurassic formation consists of ten stages, or superposed zones, limited and defined by their several fauna as distinctly as by their stratigraphical characters. In tracing them one after the other around various geological basins, we have ascertained that they are nowhere confounded, and that they represent clearly ten distinct epochs, one succeeding another in a constant and regular order. We have ascertained that the same succession takes place in the same order at all parts of the earth which have been submitted to exact observation, and that they are therefore the indications of the series of great geological phenomena which have been manifested during the Jurassic age." *

320. M. D'Orbigny has given to these ten stages names taken chiefly from the places, where their mineralogical characters have been most developed and observed. To avoid encumbering the reader with a nomenclature so complex, we shall here designate the stages according to their order of superposition, or what is the same, their dates of deposition, beginning from the lowermost

* D'Orbigny, *Paléontologie*, vol. ii. p. 419.

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or earliest, and proceeding upwards to the uppermost or latest. It may, nevertheless, be useful to indicate the names given to them in the works of M. D'Orbigny and other French geologists, annexing the estimated average thickness of the stages.

Stage.	Name.	Origin.	Thickness. Feet.
X.	Portlandian .	Portland oolite and limestone .	200
IX.	Kimmeridgian .	Kimmeridge clay	500
VIII.	Coralline . .	Coral rag	1000
VII.	Oxfordian .	Oxford clay	500
VI.	Callovian . .	Kelloway's rock	500
V.	Bathonian .	Bath oolite	200
IV.	Bajocian . .	Bayeux	200
III.	Toarcian . .	Thouars	500
II.	Liasian . .	Lias	500
I.	Sinemurian .	Semur	1000
Total thickness . . .			5100

These approximate estimates of mean thickness are much below the real measures on the slopes of the Alps, the western declivity of the Vosges, and through all the series from Avallon to Tonnerre.

321. In fig. 152 is presented a section of the Triassic and Jurassic formations extending from the Vosges to Sommevoire (Haute Marne), directed towards Paris,* where the series of strata is complete, the successive stages of each formation being marked with the Roman numerals.

322. From an elaborate examination of the strata composing these ten stages in various countries and in different parts of the globe, it appears, that during the Jurassic age, the earth was subject to all the physical vicissitudes which are at present incidental to it. During each of the ten periods there were continents and oceans. As at present, peculiar classes of marine animals inhabited the coasts, the deeper littoral parts, and the still greater depths of the ocean. Then, as now, there were submarine currents, waveworn shores, sheltered gulfs and tranquil bays. The condition of the strata proves that during this age slow undulations of the crust, such as those which are now manifested in the Scandinavian peninsula (118), were frequent. This is especially manifested by the state of the strata composing the 3rd, 4th, 5th, 6th, and 7th stages, at Chaudon, in the department of the Basses Alpes in France.

323. The Jurassic age is distinguished zoologically from the Triassic age by the absence of forty-two genera, which became

* For the continuation of this section to Paris, see § 396 and § 456.

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extinct in the latter, and from the succeeding ages of the world

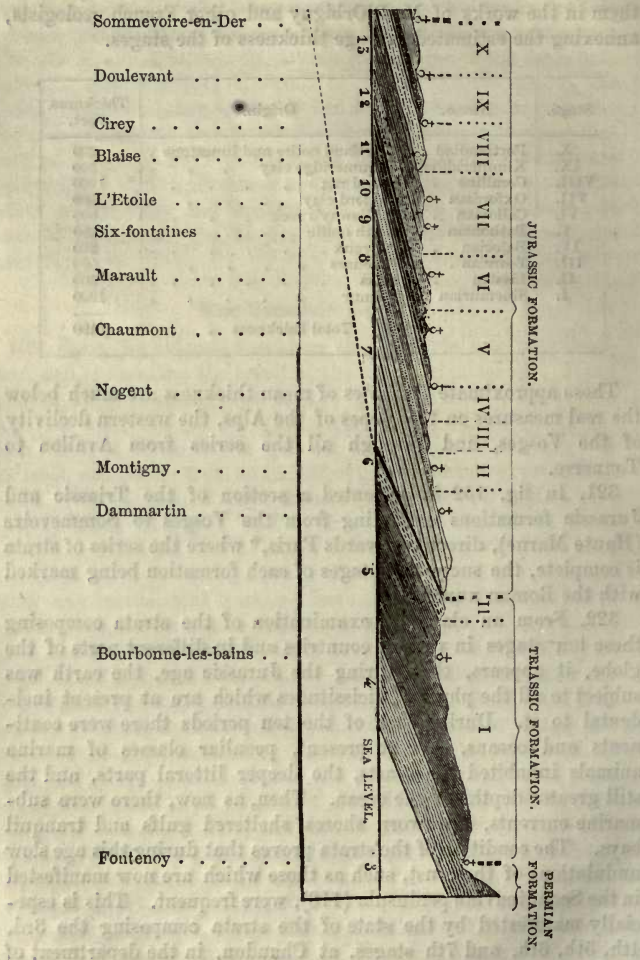


Fig. 152.—Section of the strata from the Vosges towards Paris.

by the absence of thirty-two orders of animals which had not yet appeared upon the earth, consisting of

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	Orders.
Mammifers	11
Birds	6
Reptiles	2
Fishes	3
Crustacea	2
Insects	1
Mollusca and Radiata	7

32

During this age nearly 300 new generic forms were called into existence, of which about 180 did not survive the age. This fauna consisted of about 4000 species, which were distributed among the ten periods, so that, save in very exceptional cases, no species are common to any two periods. Each period, therefore, had its own peculiar and characteristic animal kingdom.

324. To illustrate this remarkable principle, which seems to have been adhered to in all the operations of creative power from the first animalisation of the globe to the present period, we here subjoin a tabular synopsis, showing the number of species Mollusca and Radiata found in each of the ten stages, and also the number common to two or more stages.

Stages.	Species common to two or three stages.	Species limited to each stage.	Totals.
I.	1	173	174
II.	1	300	301
III.	0	288	288
IV.	7	596	603
V.	11	535	546
VI.	26	255	281
VII.	37	702	739
VIII.	27	628	655
IX.	16	183	199
X.	3	57	60
	<u>129</u>	<u>3717</u>	<u>3846</u>

But in the second column the same species is frequently repeated. Allowing for this, the total number of species which are found in more than one stage is only 56, or about $1\frac{1}{2}$ per cent. of the entire number, a proportion which is altogether insignificant, and which cannot be considered as impairing the general law that each period had its own specific fauna.

325. From a general analysis of the facts, the following conclusions may be deduced:—

1st. That during the Jurassic age of the world about 4000 specific animal forms lived, different from any which existed at any antecedent or posterior epoch.

2nd. That this total number consisted of ten distinct groups,

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which existed severally during the ten periods of the Jurassic age, their remains being deposited in the ten superposed stages which compose the Jurassic formation.

3rd. That each period, therefore, had its own special fauna, having nothing in common with the preceding or succeeding period.

4th. That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed $1\frac{1}{2}$ per cent. of the total number of species discovered.*

326. The geography of Europe in the Jurassic age has been traced and mapped with considerable precision by Messrs. Elie de Beaumont and D'Orbigny. The Jurassic formation, which has been well observed, and its limits determined, shows the extent and configuration of the seas, and consequently the outlines of the land. The Jurassic seas in Western Europe formed three principal basins, extending over certain parts of France and the eastern and southern parts of England. The form and limits of these are shown on the map (fig. 153), drawn by M. D'Orbigny, here reproduced with the permission of the author and publisher, which does not differ in any essential points from that of M. Elie de Beaumont (fig. 154), as will presently appear.

327. The Anglo-Parisian basin covering the north-west of France and the eastern division of England, was limited in England by a line directed N.N.E. from Somersetshire to Durham, passing therefore through the counties of Gloucester, Worcester, Stafford, Derby, and York; all that part of England to the east of this line being then covered by the sea.

On the other side of the Channel, the western shores of this basin passed across Normandy from St. Lo southwards to Angers on the Loire. It skirted the northern limit of the central plateau from Angoulême to Autun. On the north its shores were directed from Calais by Arras to Metz and Verdun, where they turned southwards to Chaumont. This basin communicated with the other two by two straits, one of which extended from La Rochelle to the eastern part of Angoulême, marked in the map as the Breton Strait, and the other from Chaumont to Autun, marked as the Belgi-Vosgian Strait. All that part of the channel east of Devonshire constituted part of this Anglo-Parisian basin or sea. The entire province of Brittany in France was at this epoch dry land.

328. The Pyrenean basin was limited on the north by the Breton Strait, and on the north-east by the central plateau,

* D'Orbigny, *Paleontologie*, vol. ii. p. 426.

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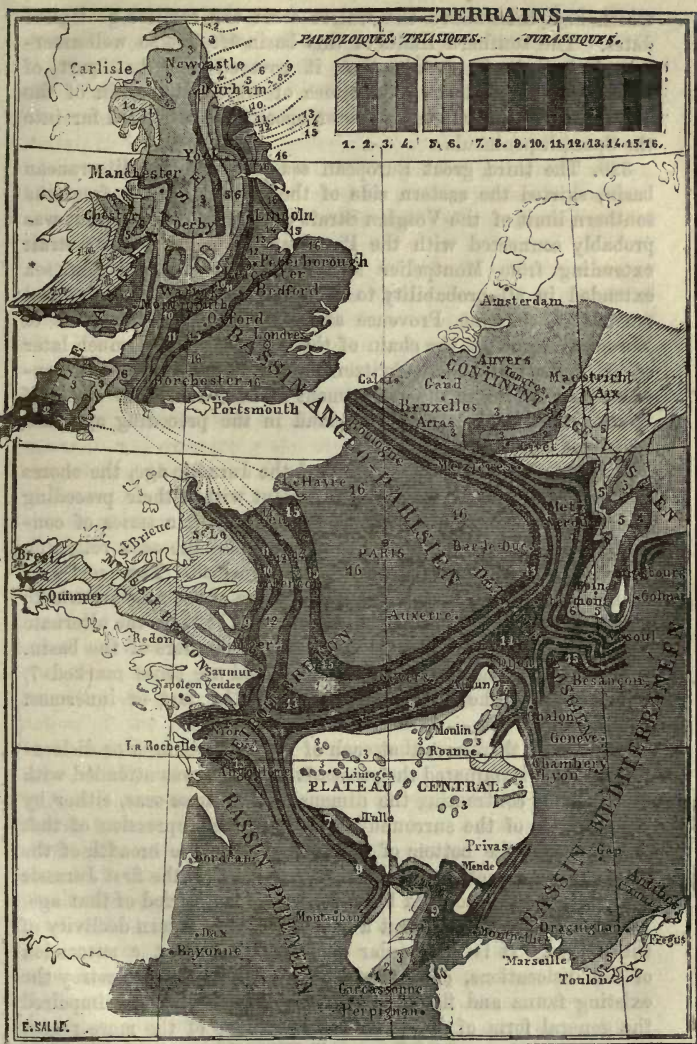


Fig. 153.*—Map showing the outlines of land and water in Western Europe in the Jurassic age. By M. D'Orbigny.

* In this map the dark shading, corresponding with the shades marked

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which had been above the waters from the earliest geological dates. The southern limits of this basin are not so well ascertained, but it is certain that it covered all that part of southern Europe, from the surface of which the chain of the Pyrenees burst upwards at a later epoch, and extended far into the Spanish peninsula.

329. The third great European sea, called the Mediterranean basin, skirted the eastern side of the central plateau from the southern limit of the Vosgian Strait to Montpellier, where it was probably connected with the Pyrenean basin by another strait extending from Montpellier to Perpignan. This ancient sea extended in all probability to a considerable distance east and north-east, covering Provence and Dauphiné, all that part of Europe from which the chain of the Alps arose at a much later epoch, and all Piedmont, Switzerland, and Italy, with the exception of an island in the department of the Var in the south of France, which was already dry land in the preceding age, and continued so.

330. At each succeeding period of the Jurassic age, the shores of these seas retired from point to point within their preceding limits, so that their successive outlines formed a series of concentric lines, one included within the other, the seas retaining their form, but contracting their dimensions. This series of changes is especially remarkable in the case of the Anglo-Parisian basin, where it is indicated on the map (fig. 153) by the alternate shadings in two different tints around the borders of the basin. The limits during the first Jurassic period are those marked 7, the second 8, the third 9, and so on, the last or innermost being 16.

It appears, therefore, that each of the disturbances or dislocations, which terminated the successive periods, was attended with the effect of contracting the dimensions of these seas, either by the elevation of the surrounding land, or the depression of that which formed the bottom of the sea. The entire breadth of the zone of land, which being covered by the seas of the first Jurassic period was left uncovered by those of the last period of that age, is found to have been about a degree on the western declivity of the Vosges. It is a singular geological fact, that a succession of ten dislocations, each of which was sufficient to destroy the existing fauna and flora, should nevertheless leave unimpaired the general form of the seas, and that none of the more recent and more violent convulsions of the succeeding ages should have

7 to 14 inclusive, are to be understood as indicating water, and the other parts land.

effaced the traces, by which the outlines of the land and water during these successive periods have been determined.

331. It will be seen by reference to the section (fig. 152), that the series of stages from the Vosges towards Paris are still in concordant superposition, being very nearly parallel and horizontal, or if they dip it is always towards the middle of the basin, as strata do when deposited at present in tranquil waters. Except some occasional faults, there are no violently inclined or disrupted strata either in the Anglo-Parisian basin or north of the Pyrenean.

When, however, the state of the stratification of these stages on the slopes of the Alps are examined, a very different state of things is encountered. There we find them broken, and thrown into all inclinations, from the vertical to the horizontal; the obvious effects of the catastrophe, which in forcing up the great chain of the Alps burst through the Jurassic formation, disrupting its stages, and throwing them upon the declivities into all inclinations. On examining the sections of the strata as they are ranged upon the slopes of the Alps, we find, notwithstanding the violence to which they have been submitted, the same regular succession of ten stages occurring in the same order as around the Anglo-Parisian basin, where they were deposited successively, and in a state of comparative tranquillity. All this indicates that for long intervals of time previous to the elevation of the chains of the Alps and Pyrenees, the region on which they now stand was covered by the Jurassic seas, upon the bottom of which the strata of the Jurassic formation were deposited, and that it was long after the consolidation of these strata, that the violent action of the fluid matter of the internal parts of the earth, breaking the crust, forced the igneous rocks which now form the Alps and Pyrenees through the disrupted Jurassic stages.

332. Observations made upon the organic deposits of the Jurassic strata fully confirm these views. The shore lines of the Anglo-Parisian and other basins, those outlines marked on the map by the differently tinted shadings, are characterised by those shells which are deposited on the very borders of seas within the play of the tides. The deposits within these are those which take place in the deeper littoral regions, but those which are found upon the section of the strata disrupted upon the slopes of the Alps and Pyrenees, are the classes known to live only in the depths of the ocean. With the exception, therefore, of certain points giving coast indications, the Alps, or rather the space on which they stand, were in the midst of the Jurassic ocean.

333. During this age the island of the Var, already mentioned, was considerably increased. The land of the Vosges and the

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Black Forest were also augmented, as well to the west in the direction of Lorraine, as to the east in the direction of Germany, where several islands, left separate in the Triassic age, became united so as to form a single island or continent of considerable magnitude. But while in some places the land was thus increased, in others it was submerged. Thus the continental tract, which in the Palæozoic age extended over France, between St. Malo and Lyons (see map of the Carboniferous period, fig. 148), was in this age submerged by the Breton Strait which connected the Anglo-Parisian and Pyrenean basins. Thus Poitiers and the surrounding region were alternately dry land and submerged by the sea, being submerged in the Silurian, dry in the Carboniferous period, again submerged during the Jurassic age, and finally raised to their present level.

334. It will be also apparent by inspecting the charts of M. Elie de Beaumont and D'Orbigny, that the tract between Toulon and Innspruck, which in the Palæozoic age was dry land, was completely submerged by the Mediterranean basin in the Jurassic age, being subsequently raised to its present elevation.

335. Owing to the extent of the Jurassic deposits in Europe, and the clearness with which they are distinguishable from those which lie below them, the outlines of land and water during that age can be traced with nearly as much precision as the geographical form of the existing continents.

336. The Jurassic geography of central Europe will be further elucidated by the map of M. Elie de Beaumont, fig. 154, here reproduced by permission from the work of M. Beudant.

The great Belgivosgian continent, a part of which only is included in the map of M. D'Orbigny, fig. 153, is here more fully represented. It appears that it extended on the north of the Mediterranean basin from Calais and Dunkirk to Cracow east and west, and from Wesel and Leipsic to Basle and Salzbουργ north and south. By reference to fig. 142, 144, it will be seen that in the Silurian and Carboniferous periods Saxony and Bohemia formed a large island, and that another extended from Frankfort to Arras. In the Jurassic age these became united by the upheaving of the land, and formed the Belgivosgian continent shown in figs. 153 and 154. A well-defined coast then extended from Dunkirk to Metz, which, after passing round the two peninsulas, the Vosges and the Black Forest, reached Ratisbon, Vienna, and Cracow, where it was intersected by a strait directed N.W. and S.E.

An island existed between Toulon and Nice, and Corsica was raised above the waters.

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Fig. 154.*—M. Elie de Beaumont's map of Western Europe in the Jurassic Age.

The Scandinavian peninsula remained unchanged since the Carboniferous period.

337. The marine animals of the Jurassic age presented characters strikingly different from those of the preceding epochs. The seas were now inhabited by monstrous animals endowed with vast powers of aquatic locomotion called Ichthyosauri, fig. 7, and

* The dark shading represents land.

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Plesiosauroi, fig. 155, whose oar-like feet resembled those of the

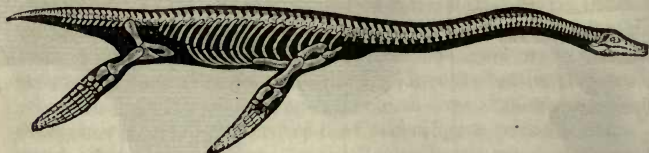


Fig. 155.—The Plesiosaurus.

present sea-tortoise. These animals replaced the sauroid fishes of the Devonian period which long before had disappeared. It was also this age which was signalised by those flying saurians to which palæontologists have given the name Pterodactyles (fig. 156), or wing-fingered. All these monstrous tribes became com-

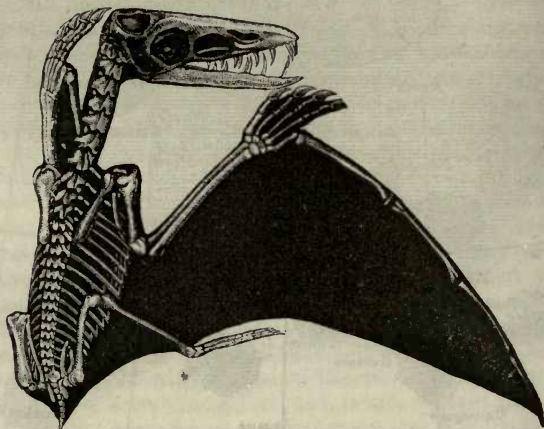


Fig. 156.—The Pterodactyle

pletely extinct at the close of the Jurassic age. In fig. 161 (p. 1) we have reproduced, after Dr. Buckland, an illustration of the zoology and botany of this age.

338. The producti had altogether, and the spirifers nearly, disappeared, but numerous terebratulæ of other species took their places. The family of ammonites (fig. 8) which had commenced to appear sparingly in the Triassic age now abounded.

This age was also signalised by the appearance for the first

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time of the family of *Calmars*, which include the Belemnites and various new bivalve Molluscs.

339. In the seas existed also madreporic reefs or islands similar to those which exist at present in intertropical regions (fig. 202). Lakes were numerous and were inhabited by tribes of fresh water Testacea, whose remains are now found in the Portland beds and elsewhere.

340. Insects of the orders Diptera (flies, gnats), Hymenoptera (bees, ants), and Hemiptera (bugs, water scorpions, plant lice), Crustaceous Isopods (sow bugs), Tectibranch-Molluscs, Cirricle-Brachiopods, free Crinoids, severally appeared in this age for the first time upon the earth.

341. The vegetable kingdom presented none of the characteristics of the preceding. The colossal ferns and lycopodiaceæ had disappeared, and had been replaced by new species of the same families. Conifers were abundant in the Lias period, with new species of Cicadeæ. The fruit of a species of palm is found in the same deposit, as well as carbonaceous strata altogether different from those of the carboniferous period. The difference of the quantity as well as the quality of these vegetable deposits indicate in a striking manner the difference of the extent of the continents of the two periods.

This general account of the Jurassic age will render necessary only a very brief notice of its successive periods.

FIRST JURASSIC PERIOD.

342. The geological convulsion which closed the Triassic age having destroyed the animal and vegetable kingdoms, and the tumult having been followed by a period of tranquillity, the seas, subsiding within their limits, deposited the strata which form the first Jurassic stage. These deposits, called by D'Orbigny the Sinemurian stage, from the circumstance of their great development in the neighbourhood of the town of Semur (Sinemurium), correspond with the lower lias of British geologists, the gryphite limestone of Dufresnoy, Elie de Beaumont, and Roemer, and the quadersandstein of other German geologists.

The parts of Europe where this stage appears at the surface round the great Jurassic basins are shown upon the map (fig. 153), by the shading marked 7, being the external boundary of the series of concentric lines surrounding these basins. In England this stage is seen in a continuous zone, extending N.N.E. from Lyme Regis, through the counties of Dorset, Somerset, Gloucester, Worcester, Warwick, Leicester, Nottingham, and Lincoln. It

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forms a semicircle in Yorkshire, directing its course to the Tees and Whitby. It will be apparent from the map that the course of this stage in England is only the continuation of its direction in Normandy.

343. This stage is distinguished from the succeeding one by many and evident discordances, and more especially by the isolation of strata, the superior stage being in many places present without the inferior. An example of this is presented at Fontaine-Étoupe-Four, in the department of Calvados in France, where the second, third, and fourth stages rest in concordant stratification on Silurian rocks, without the interposition of this first stage.

344. The seas of this period covered all the southern part of Western Europe from France to Sicily, and deposited their first stage upon the region on which the Alps and Pyrenees now stand. After the lapse of a long interval posterior to their consolidation, as well as that of many other stages subsequently deposited, the Alps and Pyrenees were forced by an internal pressure through the crust, which being broken, these with other strata were disrupted and thrown into various inclinations, some being rendered vertical, while others being compressed horizontally were bent into the form of undulations.

Examples of these effects are numerous. One showing the first Jurassic stage thrown into a vertical position occurs at Gevaudan in the department of the Basses Alpes (fig. 158), and one showing the undulating form produced by horizontal compression occurs at Chaudon à Digne in the same department (fig. 159).

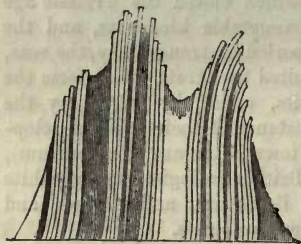


Fig. 158.—Section of first Jurassic stage at Gevaudan.

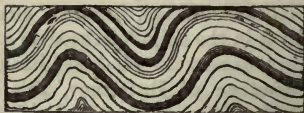


Fig. 159.—Section of first Jurassic stage at Chaudon.

345. After tranquillity was re-established, another fauna and flora was called into existence, a synopsis of which (excepting the annulata) is given in the following table :—

SECOND JURASSIC PERIOD.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the First Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	0	1	0	0
	Fishes	1	1	0	0	0
MOLLUSCA.	Cephalopods . .	4	3	1	0	0
	Gastropods . . .	9	1	8	0	0
	Lamellibranchia	20	4	16	0	0
	Brachiopods . .	6	2	4	2	0
	Bryozoa	1	0	1	0	0
RADIATA.	Echinodermata .	3	1	2	0	0
	Polyparia . . .	3	2	1	1	1
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	0	0	0	0	0
		48	14	34	3	1

The 46 genera of Mollusca and Radiata composing this fauna, so far as they are known, consisted of 174 species.

346. Among the reptiles which lived in these seas were the Ichthyosauri or great fish-lizards, already mentioned (fig. 7), which rivalled in magnitude the largest whales of the present seas. Fishes of new species animated the coasts, and Ammonites (fig. 8), Belemnites and Turrillites abounded. So many new forms signalised the commencement of a new era in animalisation.

The order of Dipterous insects appeared for the first time. A new flora adorned the continents in which new species of Cicadæ and ferns predominated.

347. The convulsion which terminated this period arose probably from a subsidence of the beds of the seas, which, after the re-establishment of equilibrium, caused them to recover their former outline, their shores being only contracted within their former limits.

SECOND JURASSIC PERIOD.

348. The deposits made by the seas of this period, called by D'Orbigny the Liasian stage, correspond with the middle lias or marlstone of British geologists, and the Belemniten-schichte of the Germans. The regions of its appearance are nearly the same as those of the preceding stage.

349. When tranquillity was re-established, a new creation was called into being, a synopsis of the chief part of which is presented in the following table :—

THE PRE-ADAMITE EARTH.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Second Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTA- BRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	3	1	2	0	0
	Fishes	29	22	7	10	9
MOLLUSCA.	Cephalopods . .	3	0	3	0	1
	Gastropods . . .	16	2	14	0	0
	Lamellibranchia .	25	3	22	1	0
	Brachiopods . .	3	0	3	0	0
	Bryozoa	0	0	0	0	0
RADIATA.	Echinodermata .	6	4	2	0	0
	Polyparia . . .	2	1	1	0	0
	Foraminifera . .	6	6	0	0	0
	Amorphozoa . .	0	0	0	0	0
		93	39	54	11	10

The genera of Mollusca and Radiata alone consisted of at least 300 species.

350. The seas swarmed with enormous Saurians in greater numbers than ever, including new varieties of the Ichthyosauri and Plesiosauri. The former had a fishlike form, and the latter a neck of enormous length, by means of which it could dart its mouth at a distant prey, its body still being immersed in the water (fig. 155). With these were associated the singular flying reptiles, called Pterodactyles (fig. 156). A vast variety of new species of fishes disputed the seas with swarms of Ammonites (fig. 8), Nautili, and Belemnites; while the coasts abounded in endless varieties of shells, such as Pterocera, Ditremaria, Inoceramus, with Asteria, Ophiuri, Echinodermata (fig. 160), and Foraminifera.

351. Although all traces of terrestrial fauna have disappeared, in the remains of this period there can be little doubt that insects and other Annulata existed. Of Crustacea only one genus, *Coleia*, has been found.

352. The land was richly clothed with vegetation, consisting chiefly of ferns, cicadeæ, and conifers of elegant foliage, of which 65 species are known.

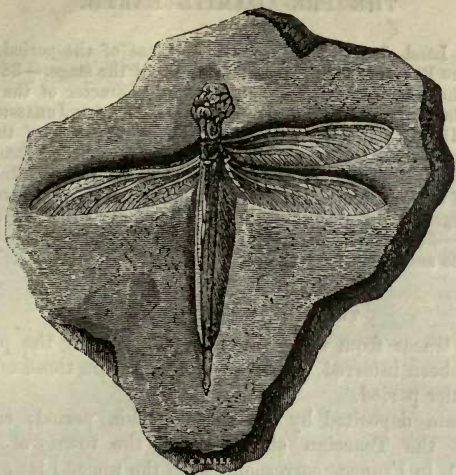


Fig. 166.—FOSSILE DRAGON-FLY (LIBELLULA).

THE PRE-ADAMITE EARTH.

CHAPTER VI.

THIRD JURASSIC PERIOD. 353. Mineral character of this stage.—354. Synopsis of the animal kingdom.—355. Outlines of land and water.—356. Land animals and vegetation. FOURTH JURASSIC PERIOD. 357. Mineral character of the stage.—358. Synopsis of the animal kingdom.—359. Land fauna. FIFTH JURASSIC PERIOD. 360. Mineral character of the stage.—361. Synopsis of the animal kingdom.—362. Examples of the fauna.—363. Traces of land fauna—Phascolotherium and Thylacotherium.—364. Examples of the flora.—365. Convulsion which closed the period. SIXTH JURASSIC PERIOD. 366. Mineral character of the stage.—367. Synopsis of the animal kingdom—disappearance of the Ichthyosauri.—368. Remarkable changes in the outlines of land and water.—369. Extent of the Mediterranean basin—submersion of the great Russian continent. SEVENTH JURASSIC PERIOD. 370. Mineral character of this stage.—371. Synopsis of the animal kingdom.—372. Creation of several orders of insects.—373. Specific forms of Mollusca and Annulata.—374. Outlines of land and water.—375. Marine flora.—376. Land animals.—377. Surprising perfection of the fossil forms—observations of Buckland and Lyell.—378. Further proofs of the suddenness of the catastrophe which terminated this period.—379. Indication of the general prevalence of tropical climate. EIGHTH JURASSIC PERIOD. 380. Mineral character of the stage.—381. Synopsis of the animal kingdom.—382. Elevation of Russia above the waters.—383. Character of the fauna.

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—384. Land flora and fauna.—385. Close of the period. **NINTH JURASSIC PERIOD.** 386. Mineral character of the stage.—387. Synopsis of the animal kingdom.—388. General character of the fauna.—389. Marine genera.—390. Land animals. **TENTH JURASSIC PERIOD.** 391. Mineral character of the stage.—392. Synopsis of the animal kingdom.—393. Outlines of land and water—marine fauna.—394. Close of the period. **The Cretaceous Age.** 395. Mineral character of the Cretaceous formation.—396. Section of the strata between the Vosges and Paris.—397. Resolution of the formation into seven stages.—398. Nomenclature and thickness of the stages.—399. Discordance and isolation of the stages.

THIRD JURASSIC PERIOD.

353. THE traces from which a convulsion closing the preceding period has been inferred, differ in nothing from those mentioned in the former period.

The strata deposited by the seas of this period, called by D'Orbigny the Toarcian stage, from the town of Thouars (Toarcium), in France, correspond with the upper Lias of British geologists, the Brauner Jura, and Opalinusthon of the Germans. Its extent can be traced on the map (fig. 153), by the shading marked 9.

354. The new creation, exclusive of the Annulata, is shown in the following table:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Third Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	6	3	3	3	3
	Fishes	11	2	9	1	1
MOLLUSCA.	Cephalopods . .	7	4	3	3	3
	Gastropods . .	17	0	17	1	0
	Lamellibranchia	29	2	27	0	0
	Brachiopods . .	4	0	4	1	0
	Bryozoa	0	0	0	0	0
RADIATA.	Echinodermata .	2	0	2	0	0
	Polyparia . . .	3	2	1	2	2
	Foraminifera . .	3	2	1	0	0
	Amorphozoa . .	2	0	2	0	0
		84	15	69	10	9

The Mollusca and Radiata consisted of 288 species.

355. The outlines of land and water did not suffer any considerable change. Besides the genera of marine reptiles already mentioned, the strange forms of the Mistriosauri and Macrospondili

THIRD JURASSIC PERIOD.

now roamed along the coasts, besides various new forms of Mollusca and Radiata.

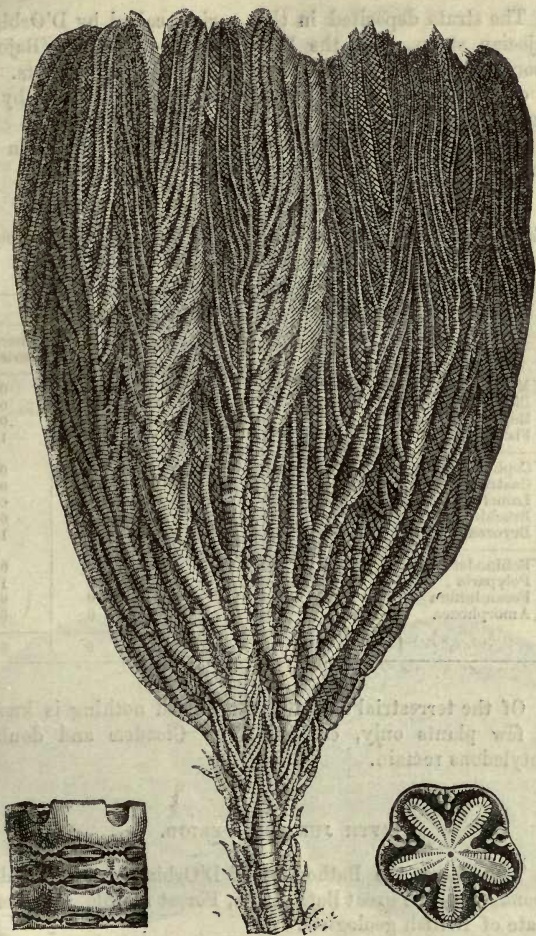


Fig. 160.—*Pentacrinus fasciculosus* (Echinoderm.)

356. Scarcely a trace of land animals remains, and those of plants but few and rare. Some conifers and cryptogamous plants however are found.

THE PRE-ADAMITE EARTH.

FOURTH JURASSIC PERIOD.

357. The strata deposited in this period, called by D'Orbigny the Bajocian stage, from the French town of Bayeux (Bajoce), correspond with the inferior Oolite of British geologists. Its course on the surface is indicated on the map (fig. 153) by the shading number 10.

358. The animal kingdom of this period is shown in the following table :—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fourth Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	0	0	0	0	0
	Fishes	5	2	3	1	1
MOLLUSCA.	Cephalopods . .	6	3	3	0	0
	Gastropods . .	21	4	17	1	0
	Lamellibranchia	40	6	34	1	C
	Brachiopods . .	5	1	4	0	0
	Bryozoa	8	8	0	1	1
RADIATA.	Echinodermata .	14	10	4	1	0
	Polyparia . . .	18	7	11	1	1
	Foraminifera . .	2	1	1	0	0
	Amorphozoa . .	10	3	7	0	0
		129	45	84	6	3

359. Of the terrestrial fauna of this period nothing is known, and a few plants only, consisting of Cicadeæ and doubtful Monocotyledons remain.

FIFTH JURASSIC PERIOD.

360. This stage, the Bathonian of D'Orbigny and D'Halloy, corresponds with the great Bath oolite, Forest marble, and Stonesfield slate of British geologists.

361. When tranquillity was re-established after the catastrophe which terminated the fourth period, a new creation appeared on the earth, of which the chief part is shown in the following table :—

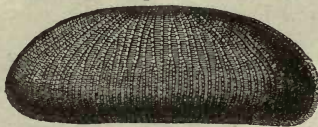
FIFTH JURASSIC PERIOD.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fifth Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	2	2	0	2	2
	Birds . . .	0	0	0	0	0
	Reptiles . . .	5	4	1	1	1
	Fishes . . .	21	5	16	5	3
MOLLUSCA.	Cephalopods . .	5	0	5	0	0
	Gastropods . .	25	6	19	0	0
	Lamellibranchia	38	4	34	0	0
	Brachiopods . .	6	0	6	0	0
	Bryozoa . .	19	9	10	2	1
RADIATA.	Echinodermata .	20	6	14	1	0
	Polyparia . . .	19	8	11	4	3
	Foraminifera . .	5	0	5	1	0
	Amorphozoa . .	10	1	9	1	1
		175	45	130	17	11

362. An example of the polyparia of this period is shown in figs. 160, 161*, 162.

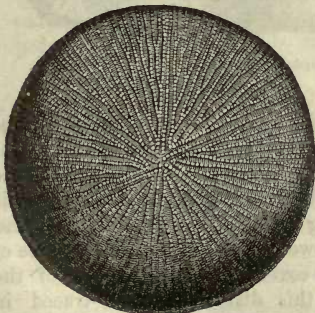
Fig. 161*.



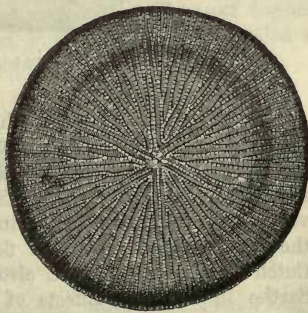
Side view.

Fig. 162.

Fig. 163.



Upper surface.



Lower surface.

Anabacia orbulites (Polyparia).

Together with new species of Pterodactyles, fig. 156, there lived in the seas of this period not less strange reptile forms, to which the names Pœcilopleuron, Teleosaurus, and Megalosaurus have been given.

THE PRE-ADAMITE EARTH.

363. A terrestrial fauna at length left traces of its existence. Mammifers now presented their first traces. Two land monsters, referred to this class, found in this stage, have been called *Phascolotherium* and *Thylacotherium*. Specimens of the lower jaw of the former were found in the oolitic limestone of Stonesfield. It is a small animal allied to the Marsupial family, and takes its name from the *Phascolomys* of New South Wales.

364. A great variety of species of ferns, *Cicadeæ*, and conifers have been found among the remains of this period, with a few *Marsileaceæ*, *Lycopodiaceæ*, and *Equitaceæ*.

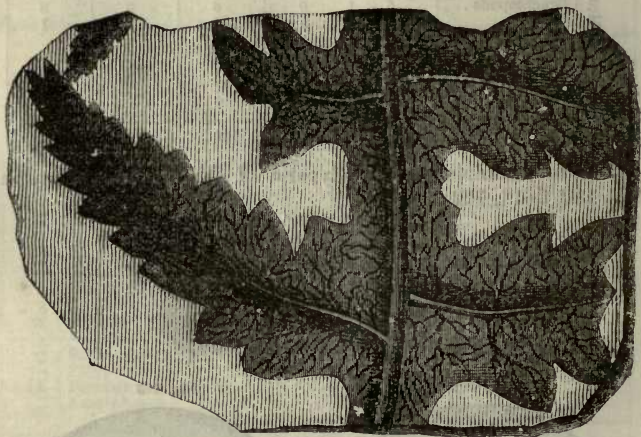


Fig. 164.—*Phlebopteris Phillipsii*.

365. One of the causes which are assigned to the catastrophe which closed this fifth Jurassic period, is the sudden sinking of the continent, which was elevated at the close of the palæozoic age, and which extended over Central and Northern Russia. This vast tract was submerged during the sixth Jurassic period, and the ocean at the same time flowed over the entire province of Cutch in India. The sea also covered the department of the Sarthe in France. Effects of this disturbance are traced in France, even where no disturbance of strata exists by the state of the superposed littoral deposits. Its effects are also seen in the polishing of the superior strata at Lyons, showing the result of a long-continued action of the waters. In fine, these indications are confirmed by the complete destruction of the fauna and flora of the period.

SIXTH JURASSIC PERIOD.

SIXTH JURASSIC PERIOD.

366. This stage, called the Callovian, corresponds to the Oxford clay and Kelloway Rocks of the British geologists, from the latter of which it takes its designation.

367. The animal generic forms which lived in this period, exclusive of the Annulata, are enumerated in the following table :—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Sixth Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	2	1	1	1	0
	Fishes	2	?	2	?	
MOLLUSCA.	Cephalopods . .	6	2	4	1	1
	Gastropods . . .	15	0	15	0	0
	Lamellibranchia	31	0	31	0	0
	Brachiopods . .	3	0	3	0	0
	Bryozoa	2	0	2	0	0
RADIATA.	Echinodermata .	11	0	11	0	0
	Polyparia . . .	1	0	1	0	0
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	0	0	0	0	0
		73	3	70	2	1

It appears, therefore, that of the 73 genera which existed, only three were new, two of which were generic forms of Cephalopods, called *Rhychoteuthis* and *Palæoteuthis*. This period was



Fig. 165.—Ammonite—Jason.

remarkable for the prevalence of Ammonites, denominated *Limula*, *Athleta*, *Jason* (fig. 165), as well as the *Trigonia elongata*, *Plicatula peregrina*, *Astrea dilatata*, and *Terebratula Diphya*.

The *Ichthyosaurus* appeared for the last time in this period.

368. The outlines of sea and land during this period underwent some remarkable changes. The convulsions which ter-

THE PRE-ADAMITE EARTH.

minated the fifth period raised the bottoms of the Breton and Vosgian Straits, so as to separate completely the Anglo-Parisian from the Pyrenean and Mediterranean basins, and thus to connect Brittany on the one side, and the Vosgian continent on the other, by two isthmuses.

369. The Mediterranean basin extended across the Tyrol, and into Switzerland, as far as Soleure, and probably even to the Crimea. But the greatest change produced by this convulsion was the subsidence of the great Russian continent, which had continued above the sea since the close of the palæozoic age, and the consequent extension of the seas of this sixth period over all Russia, from the 48th degree of latitude to the Frozen Ocean. It appears also from the organic remains of Mollusca and Radiata, that these seas extended on the south, without interruption, to the 9th degree of latitude, thus covering the entire extent of Asia, from the province of Cutch to the polar circle.

SEVENTH JURASSIC PERIOD.

370. The deposits of this period, called by D'Orbigny the Oxfordian stage, correspond with the upper strata of the Oxford clay, or the dark-blue clay of Oxfordshire and the Midland counties, the thickness of which in England, according to Lyell, is sometimes 500 feet. In the south-west of France, and in the Alps, it measures from 320 to 500 feet.

371. In the following table we give a synopsis of the generic forms of this period, excepting the Annulata:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Seventh Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	{ Mammifers . .	0	0	0	0	0
	{ Birds	0	0	0	0	0
	{ Reptiles . . .	11	10	1	9	9
	{ Fishes	28	14	14	18	13
MOLLUSCA.	{ Cephalopods . .	9	5	4	2	2
	{ Gastropods . .	21	0	21	0	0
	{ Lamellibranchia	41	2	39	1	1
	{ Brachiopods . .	8	0	8	0	0
	{ Bryozoa . . .	4	0	4	0	0
RADIATA.	{ Echinodermata .	22	9	13	8	7
	{ Polyparia . . .	22	6	16	4	3
	{ Foraminifera . .	0	0	0	0	0
	{ Amorphozoa . .	16	5	11	3	2
		182	51	131	45	37

SEVENTH JURASSIC PERIOD.

Of Crustacea 31 were created, all of which became extinct at the close of the period, so that the total number of generic forms ascertained to have lived is 213, of which 82 were created, and 131 revived, exclusive of other Annulata, the existence of which has been determined but their numbers unascertained.

372. This period is signalised by the first appearance of insects, of the orders Hemiptera (bugs, water-scorpions, plant-lice), Hymenoptera (bees, ants), and Lepidoptera (butterflies, moths), and of Isopodous Crustacea, and the prevalence of testaceous spongearia, pterodactyles, pycnodide fishes, and decapod crustacea.

373. Of Mollusca and Annulata of this period, 729 species have been catalogued, and the total number of species of all classes could not have amounted to less than 800.

In fig. 166 is shown a specimen of the insects of this period, and in fig. 167, one of the Annelids.

374. The seas retained their former limits; those of the Parisian and Pyrenean basins, however, retiring as before stated, so as to leave a new band of surrounding coast uncovered. They extended over the same parts of Europe, and were continuous on the one side to Asia Minor, and on the other into Russia, as is proved by the prevalence of the same marine species in the strata. The Breton and Vosgian Straits were still replaced by isthmuses.

375. Adolphe Brongniart has enumerated a considerable assemblage of marine plants of this period, consisting chiefly of Cryptogamous Algæ.

376. The continents were not less animated than the seas. Besides several orders of insects, and the generic reptile forms of the preceding periods, 10 new reptile genera were called into existence, including the Gnathosaurus, Pleurosaurus, Geosaurus, and Spondylosaurus, which, as well as new species of pterodactyles, abounded. M. Brongniart has also given a list of the

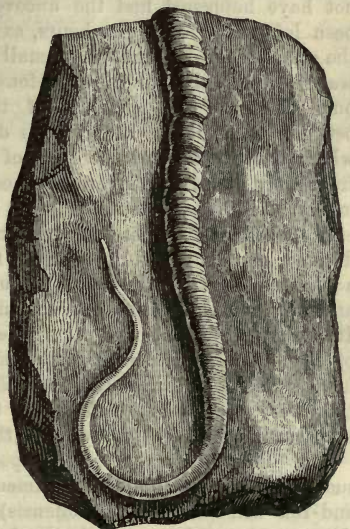


Fig. 167.—Serpula flagellum.

THE PRE-ADAMITE EARTH.

terrestrial flora of this period, which consisted in a great degree of doubtful monocotyledons.

377. The sudden character of the catastrophes, by which from period to period the successive faunas and floras were destroyed, is strikingly illustrated by the perfect state in which the remains of many of the saurians have been found. Of those which were deposited in these strata, many must, as Sir C. Lyell observes, have met with sudden death and immediate burial, and the same indications are observable in the case of all the other stages. "Sometimes," says Dr. Buckland, "scarcely a single bone has been removed from the place it occupied during life, which could not have happened had the uncovered bodies of these saurians been left, even for a few hours, exposed to putrefaction, and to the attacks of fishes and other small animals at the bottom of the sea."* Not only are the skeletons of the Ichthyosauri entire, but sometimes the contents of their stomachs still remain between their ribs, so that we can discover the species of fish on which they lived, and the form of their excrements. Not unfrequently there are layers of these coprolites (fossilised excrements) at different depths in the lias at a distance from any entire skeletons of those marine lizards, from which they were derived, as if the muddy bottom of the sea received small sudden accessions of matter from time to time, covering up the coprolites and other exuviae, which had accumulated during the intervals. It is further stated, that at Lyme Regis, those surfaces only of the coprolites, which lay uppermost at the bottom of the sea, have suffered partial decay from the action of the water, before they were covered and protected by the muddy sediment that had afterwards permanently enveloped them.†

378. The remains of cephalopods give like indications of sudden death. Numerous specimens of the Calamary, or pen-and-ink fish (*Geotenthis Bollensis*), have also been met with in these strata at Lyme, with the ink-bags still distended, containing the ink in a dried state, chiefly composed of carbon and but slightly impregnated with carbonate of lime. These, like the Saurians, must therefore have been promptly buried, for if long exposed after death, the membrane containing the ink would have been decayed.‡

379. The identity of the specific forms of the fauna of this period, in all latitudes, from 40° to the Frozen Ocean, shows that

* Bridg. Treat. p. 125.

† Lyell's Manual, p. 327 ; De la Beche, Geol. Res., p. 334 ; Buckland, Bridg. Treat., p. 307.

‡ Buckland, Bridg. Treat., p. 307.

EIGHTH 'JURASSIC PERIOD.

no difference of climates such as the present then existed. All had the intertropical character.

EIGHTH JURASSIC PERIOD.

380. The strata deposited during this period, called by D'Orbigny the Coralline stage, correspond to coral rag of British and German geologists.

381. Exclusive of annulata, the following table represents the fauna of this period.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Eighth Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	1	0	1	0	0
MOLLUSCA.	Cephalopods . . .	3	0	3	0	0
	Gastropods	28	2	26	2	0
	Lamellibranchia . .	41	2	39	2	1
	Brachiopods . . .	4	0	4	0	0
	Bryozoa	3	0	3	0	0
RADIATA.	Echinodermata . .	24	5	19	11	3
	Polyparia	48	26	22	25	19
	Foraminifera . . .	3	1	2	1	1
	Amorphozoa . . .	6	0	6	0	0
		161	36	125	36	24

382. In Russia, all that tract which extended to the Frozen Ocean, and which had been submerged during the seventh period, was now again raised above the waters, and became land. In England, France, and Germany the general forms of the land remained the same, but their extent was augmented by the general retirement of the shores of the seas.

383. The fauna of this period was remarkable for numerous polyparia of the coral class, by which reefs were formed similar to those which exist in the present seas. It was at this epoch that the Diceras, Nerinea, Purpurina, Hemicidaritis (figs. 168, 169), Acrocidaris, Millecrinus, and Apiocrinus attained their greatest specific development.

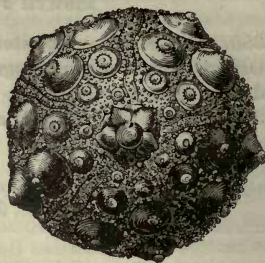
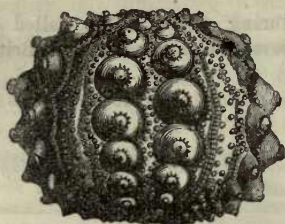
384. In the total absence of all organic remains of a terrestrial fauna, we must infer by analogy that the fauna of this must have been related to that of the antecedent periods. The flora, according to the observations of M. Brongniart, consisted of ferns, cicadeæ, and conifers of peculiar species.

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385. Although it is probable that the close of this stage was the result of a convulsion which originated at some point distant

Fig. 169.

Fig. 168.



Hemicidaris crenularis.

from the range of geological observation, there are indications of some disturbance by the absence of the superior strata in the Alps, from Grasse to Gap, which may probably be connected with the catastrophe which closed this eighth period.

NINTH JURASSIC PERIOD.

386. The deposits of this period correspond with the Kimmeridge clay of the British geologists.

387. A general view of the fauna, with the usual exceptions, is presented in the following table.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Ninth Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	7	4	3	4	1
	Fishes	7	?	7?	3	?
MOLLUSCA.	Cephalopods . .	3	0	3	0	0
	Gastropods . .	15	0	15	0	0
	Lamellibranchia	31	0	31	3	0
	Brachiopods . .	3	0	3	0	0
	Bryozoa	1	0	1	0	0
RADIATA.	Echinodermata .	10	0	10	1	0
	Polyparia . . .	1	0	1	0	0
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	1	0	1	0	0
		70	4	75	11	1

TENTH JURASSIC PERIOD.

388. The close of the last period was marked by the final extinction of at least 36 generic forms. The four generic forms of reptiles which appear for the first time in this ninth period are the *Stenosaurus*, *Streptospondylus*, *Emys*, and *Platemys*, of which the *Stenosaurus* is peculiar to the period and characteristic of it, not re-appearing in the next or any subsequent period. Of the reptile genera of former periods, those which re-appear in the present, and finally became extinct at its close, are the *Plesiosaurus*, *Teleosaurus*, and *Pliosaurus*.

Independently of the species of the other classes which lived in this period, 186 species of mollusca and radiata have been catalogued and described by M. D'Orbigny.

389. The seas were circumscribed by nearly the same limits, retiring nevertheless a little within their former shores. They were inhabited by nearly the same assemblage of genera, the species being, however, altogether different. The cephalopods were not numerous, the prevailing marine genera consisting of gastropods, and lamellibranchia.

390. The land, independently of some revived genera, was inhabited by the saurian reptiles *Stenosaurus* and *Streptosaurus*, and by the tortoise forms, denominated *Emys* and *Platemys*, all of which were probably amphibious.

No vegetable remains of this period have been found.

TENTH JURASSIC PERIOD.

391. The deposits of this period correspond with the Portland beds. They lie generally upon the Kimmeridge strata of the preceding period.

392. A general view of the fauna, with the previous exceptions, is given in the table on the next page.

Of the mollusca and radiata 63 species have been described.

393. The seas of this period, like those of the former, preserved the general configuration of their outlines, still retiring a little within their former shores. The marine fauna among fishes was increased by the *Meristodon*, and among mollusca by the *Cyclas*. The principal saurians of the last period disappeared from the coasts, and were replaced by the *Cetiosaurus*. This marine reptile must have rivalled the existing whale in magnitude, some specimens indicating a total length of 40 to 50 feet. The bones found in some strata in England, of somewhat more recent date, may have been carried up from the sea along the bed of a river by the tide, or the animal when living, as is often at present the case with existing cetaceans, may have wandered up the river, and dying, have been deposited in its bed.

THE PRE-ADAMITE EARTH.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Tenth Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	2	1	1	0	0
	Fishes	6	1	5	2	1
MOLLUSCA.	Cephalopods . .	3	0	3	0	0
	Gastropods . . .	6	0	6	1	0
	Lamellibranchia	16	1	15	0	0
	Brachiopods . .	0	0	0	0	0
	Bryozoa	0	0	0	0	0
RADIATA.	Echinodermata .	2	0	2	0	0
	Polyparia	1	0	1	0	0
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	0	0	0	0	0
		36	3	33	3	1

394. The close of this period, which marks the termination of the Jurassic age, is distinctly indicated by numerous dislocations and isolations of the strata, denoting upheavings and depressions in many regions. These phenomena demonstrate the complete separation of the last stages of the Jurassic from the first of the succeeding age. M. Elie de Beaumont considers the catastrophe which raised the mountain systems of the Côte d'Or (215), of Monte Pila, and the Erzgebirge, the prevailing direction of which is W. 40° S. and E. 40° N., as that which terminated the Jurassic age.

The Cretaceous Age.

395. The group of strata to which geologists have given the name of the Cretaceous or chalk formation, being deposited upon the Jurassic group, must have been the result of the succeeding geological age. Its stratigraphical limits, as we shall here consider it, are the Purbeck beds below, and the Maestricht beds above. Some British geologists, including Sir C. Lyell, place the former as the uppermost strata of the Oolitic formation; while others, including Sir H. de la Beche, give it to the Cretaceous group. By reference to the tabular section (47), it will be seen that the title given to this Cretaceous group must not be understood as implying that chalk is the exclusive character of the strata.

The superior strata of this formation are not present in England, and hence they take their name from Maestricht, where they are most developed.

CRETACEOUS AGE.

396. The complete series of strata of the Cretaceous formation, are found succeeding each other in their proper order in the continuation of the section given in fig. 152. This continuation, extending from Sommevoire and Vassy to Vertus, is given in fig. 170. The Cretaceous group terminates a little to the west of Vertus, and the Tertiary or succeeding formation appears from that point to Paris. We shall refer to this latter part of the section when we come to notice the Tertiary age.

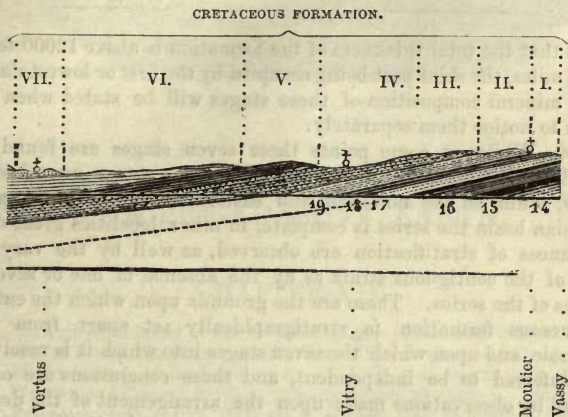


Fig. 170.—Section from Vassy to Vertus, being part of the great section from the Vosges to Paris.

397. Proceeding upon observations and reasoning similar to those explained in reference to the Jurassic formation (322), M. D'Orbigny resolves the Cretaceous formation into seven stages, to which names are given, derived from the localities severally where the strata are most exposed at the surface, and where therefore they have been most observed. To avoid encumbering the memory of the reader with a nomenclature so complex, we shall here, as in the former cases, designate the stages by their numerical order, proceeding from the lowest upwards, and the periods of their deposition into which the Cretaceous age is resolved, also by their numerical order, proceeding from the earliest to the latest.

398. It will be convenient, however, as in the former case, to indicate the names given to the stages and their approximate mean thickness severally.

THE PRE-ADAMITE EARTH.

No. of stage.	Name.	Origin.	Thickness. Feet.
VII.	Danian . . .	Denmark	50
VI.	Senonian . . .	Sen (Senones)	1000
V.	Turonian . . .	Touraine	700
IV.	Cenomanian . .	Mans (Cenomanum)	1600
III.	Albian . . .	Aube (Alba)	150
II.	Aptian . . .	Apt (Apta Julia)	700
I.	Neocomian . .	Neufchatel (Neocomum)	8000
Total			12200

So that the total thickness of the formation is above 12000 feet, or $2\frac{1}{2}$ miles, the chief part being occupied by the first or lowest stage. The mineral composition of these stages will be stated when we come to notice them separately.

399. While at some points these seven stages are found in regular superposition, in others particular stages are absent. Thus, while on the northern and eastern border of the Anglo-Parisian basin the series is complete, in other localities great discordances of stratification are observed, as well by the varying dips of the contiguous strata as by the absence of one or several stages of the series. These are the grounds upon which the entire Cretaceous formation is stratigraphically set apart from the Jurassic, and upon which the seven stages into which it is resolved are inferred to be independent, and those conclusions are confirmed by observations made upon the arrangement of the deposition of the organic remains, which appear to be distributed in seven distinct layers, corresponding with the stratigraphical limits of the stages.

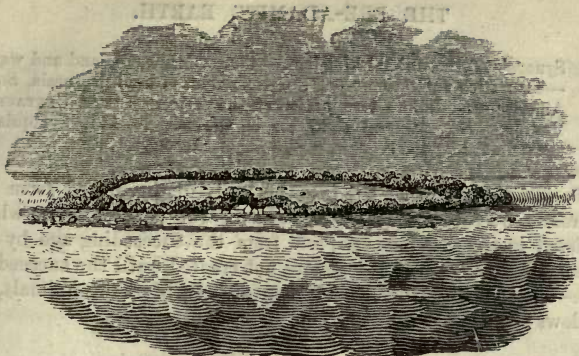


Fig. 202.—CORAL REEF.

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CHAPTER VII.

400. Zoological character of the Cretaceous age.—401. Distribution of the species among the stages.—402. General conclusions.—403. Changes of the outlines of land and water.—404. Elie de Beaumont's map of Western and Central Europe—great geographical changes.—405. The Pyrenean basin.—406. Outlines of sea and land in Central Europe.—407. Site of the Alps.—408. Cretaceous geography of France and England—D'Orbigny's map.—409. Anglo-Parisian basin.—410. The changes incidental to it from period to period.—411. Outlines of the basin in England.—412. Pyrenean basin—Mediterranean basin.—413. Animal kingdom—uniform tropical climate at all latitudes.—414. Prevalence of undulations of the surface—seven violent perturbations. FIRST CRETACEOUS PERIOD. 415. Dimensions and mineral composition of the stage—synopsis of animal kingdom. 416. Reptiles of this period—Iguanodon and Hylæosaurus.—417. Flora of this period. SECOND CRETACEOUS PERIOD. 418. Mineral character of the stage.—419. Synopsis of animal kingdom.—420. Outlines of land and water.—421. Marine fauna.—422. Vegetable kingdom.—423. Uniform tropical climate.—424. Close of the period.—THIRD CRETACEOUS PERIOD : 425. Mineral character of the stage.—426. Synopsis of the animal kingdom.—427. Outlines of land and water.—428. Marine and terrestrial fauna.—429. Close of the period.—FOURTH CRETACEOUS PERIOD. 430. Mineral character of the stage.—431. Synopsis of the animal kingdom.—432. Outlines of land and water.—433. Marine fauna.—434. Marine flora.—435. Undulations of the ground.—436. Close of the period. FIFTH CRETACEOUS PERIOD. 437. Mineral character of the stage.—438.

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Synopsis of the animal kingdom.—439. Outlines of land and water.—440. Rich vegetation.—441. Great extent of land in Russia, South America, and India—termination of the period. SIXTH CRETACEOUS PERIOD. 442. Mineral character of the stage.—443. Synopsis of the animal kingdom.

400. THE Cretaceous age is zoologically distinguished from the Jurassic by the absence of upwards of 180 generic forms which existed in the previous age, and from the succeeding age by the absence of upwards of 500 genera not created until the succeeding one—these 500 genera consisting of 24 orders of animals, as follows :

	Orders.
Mammifers	11
Birds	5
Reptiles	2
Fishes	1
Crustacea	2
Insects	1
Mollusca and Radiata	2
Total	<hr/> 24 <hr/>

401. During this age about 270 genera were created, but it is by the specific forms that its fauna can be more distinctly characterised. These consisted of about 5000 species, of which about 700 belonged to the vertebrata and annulata. The manner in which the species of mollusca and radiata are distributed among the stages is as follows :—

Stages.	No. in two or more species.	No. limited to each stage.	Totals.
I.	7	544	551
II.	8	148	156
III.	8	402	410
IV.	8	841	849
V.	3	377	380
VI.	5	1574	1579
VII.	3	63	66
	<hr/> 42	<hr/> 4249	<hr/> 4291 <hr/>

The same species being repeated in the second column, a corresponding deduction from the total number of common species must be made, which will reduce the actual number of such common species to 21, being only a half per cent. of the total number.

402. From a general analysis of the facts, the following conclusions may be inferred :—

1° That there existed in the Cretaceous age above 5000 species of animals altogether distinct from those of the preceding and

following ages, and which therefore are characteristic of the Cretaceous age.

2° That this total number consisted of seven distinct groups, which existed successively during the seven periods of the Cretaceous age, their remains being deposited in the seven superposed stages which compose the Cretaceous formation.

3° That each period therefore had its own special fauna, having nothing in common with those of the preceding or succeeding periods.

4° That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed a half per cent. of the total number of species discovered.

403. When tranquillity had been re-established after the catastrophe which closed the Jurassic age, the changes which had taken place in the levels of the solid surface of the earth caused the waters to settle into new beds, and gave a modified outline to land and sea. The contours of the seas of this period are now shown by the forms and limits of the Cretaceous strata, subsequently raised above the waters.

404. The outlines of land and water in Western and Central Europe, in the Cretaceous age, as sketched by M. Elie de Beaumont, are shown in the map (fig. 171).

The three great islands of the Jurassic age which appear in the map (fig. 154), were now connected, and their coast-lines completely changed. The northern part of Belgium was submerged, and Brussels, which in the former age was inland, was now on the coast. Arras, Calais, and Dunkirk, which were on or near the coast, were now at the bottom of a large gulf, in the midst of which was Paris, and at the southern part Tours. The town of Poitiers, which was situate in a strait, was now on the coast of the southern extremity of this gulf, which the reader will readily identify with the Anglo-Parisian basin so often referred to. London and Cambridge were at the bottom of this sea, the shores of which, bending westward, formed a bay, which might be called the gulf of Exeter, that city being at its westward limit. Oxford was on the coast of England, which, after jutting out eastward to a point near the site of Cambridge, turned northwards to Edinburgh. Holland and a large part of Prussia and Poland, including the cities of Amsterdam, Hamburg, Berlin, and Warsaw, were altogether submerged.

An isthmus connected the central tract of France with Brittany, at that time part of a continent, which, extending across the channel, was continued to the extreme north of Scotland, being there probably united with the Hebrides.

THE PRE-ADAMITE EARTH.



Fig. 171. *—Map of western and central Europe in the Cretaceous Age, sketched by M. Elie de Beaumont.

405. The Pyrenean basin, as will presently appear, did not exist at the commencement of the Cretaceous age, but subsequently to its third period reappeared, its waters covering the greater part of Spain, including Madrid, Burgos, and other towns, as shown on the map. Marseilles and Perpignan were at the bottom of a strait which bounded the southern part of the great central tract. A large

* The dark shading represents land.

island extended in the direction N.N.E. and S.S.W. from Briançon to Innspruck, separated from the main tract by a strait which covered that part of Europe now occupied by Switzerland and the chain of the Swiss Alps. A local sinking of the land between Dresden, Prague, and Brünn, in the middle of Germany, produced an extensive lake in that country, which in the Jurassic age was an uninterrupted tract of land. See map, fig. 154.

406. The Vosges Mountains, previously washed by the ocean, were now completely enclosed by the continental tract which connected Bohemia with the central plateau of France. The sea, which covered so large a part of these countries, now retired, leaving Langres, Nevers, Autun, and Lyons within the land. The south-eastern coast of the great central continent extended from Cracow a little to the north of Vienna and Munich, both of which were covered by the Mediterranean basin, following Strasburg, Bâle, and Lyons, to Carcassonne, where the Pyrenean and Mediterranean basins were connected by a strait between Perpignan and Bayonne. Bordeaux on the west and Avignon on the east were at the bottom of the sea.

407. The future base of the chain of the great Alps was then marked by the island already mentioned, which appears on the map between Salsburg and Briançon, on which Turin, Trente, and Innspruck are now placed. Toulon was on an island to the south of this, and Corsica already formed an island further south. The chief part of Italy was at the bottom of the Mediterranean basin. The Scandinavian peninsula had remained nearly as in the Jurassic age.

408. The geography of France and England during the Cretaceous age is shown upon a large scale and with more detail in the map (fig. 172), drawn by M. D'Orbigny and reproduced here by permission. In this map the seas are marked with the dark shading, and those parts which in previous ages were submerged are shown by three tints, indicated at the top of the map. The deposits of six of the successive periods of the Cretaceous age are marked as follows :—

I 17	III 19	V 21
II 18	IV 20	VI 22

409. It will be seen that the borders of the Anglo-Parisian basin on the south-east were, as in the former age, gradually contracted from period to period, that of the first period (17) being outermost, the next (18) within it, and so on, one being within the other until the last period. This regular succession of deposits is observable to a certain point of the border near Nevers, on the map, beyond which on south and west the exterior band of deposit is not, as

THE PRE-ADAMITE EARTH.



Fig. 172.—Map of France and England in the Cretaceous Age, drawn by M. D'Orbigny.

before, that of the first, but that of the fourth Cretaceous period (20).

410. The interpretation of this fact is evidently a change of relative level of the land along this border during the first four periods of the Cretaceous age. In the first, second, and third periods the border was subject to a gradually increasing depression, which after each period caused the shore of the sea to advance outwards, the shore of the second period (18) being outside that of the first (17), that of the third (19) outside that of the second (18), and in fine that of the fourth (20) being outside that of the third (19). The consequence of this is, that the fourth stage of the Cretaceous formation along this part of the coast lies over and conceals the previous deposits forming the first (17), second (18), and third (19) stages. But after the fourth period the relative levels must have undergone a contrary change, causing the borders of the sea to have retired inwards, or eastwards, from period to period, so that between the fourth and fifth period a band of deposit of the fourth stage (20) remained uncovered, and after the next period another (21), and so on to the end of the Cretaceous age.

411. The irregularity indicated above, as having taken place on the western side of the Paris basin, might have been expected to have continued across the channel, and to reappear along the English border of the same basin. Such, however, is not found to be the case; for, as indicated in the map, the successive stages of the Cretaceous period from the first (17) to the last appear along the northern border of the basin from Dorsetshire to Yorkshire, succeeding each other in the same regular order as in the southern border in France. It would, therefore, appear that the undulation which produced the irregularity observable along the western border adjoining Brittany must have been littoral; that is, in a direction at right angles to the N.W. and S.E. borders of the basin.

412. An examination of the Pyrenean basin discloses a singular state of things in accordance with that observed in the western border of the Parisian basin. The first three stages of the Cretaceous formation are altogether absent from the Pyrenean basin, which only received the deposits of the four last periods. M. D'Orbigny has inferred from this that during the first three periods of the Cretaceous age, the ground upon which the Pyrenean basin is placed was raised above the level of the sea, but that the convulsion which closed the third Cretaceous period caused it again to sink so as to be covered by the sea, and that it thus remained submerged during the last four Cretaceous periods. The border retiring from period to period is indicated on the map,

THE PRE-ADAMITE EARTH.

so as to leave band after band of the successive deposits each uncovered by the other along its NE. border.

In the Mediterranean basin all the stages are presented, though in an irregular and dislocated state.

413. The animal kingdom during the Cretaceous age was destroyed and reappeared in each of the seven periods. To the terrestrial animals, such as birds, reptiles, and insects, and the marine animals included in the class of fishes, mollusca, echinodermata, polyparia, foraminifera, and amorphozoa, which previously existed, must be joined for this age cycloid and etenoid fishes (salmon and perch), and various forms of foraminifera hitherto unknown. This age was also signalised by the prevalence of cirridated brachiopods, bryozoa and testaceous spongiaria. Ammonite shells also, of the most elegant and various forms, abounded, which disappeared for ever after this epoch.

The presence during the entire Cretaceous age of the same genera and species of animals, from the line to the 56° of latitude on both sides of the world, prove that these regions, so entirely different in their climate at present, had a uniform temperature, proceeding evidently from the neutralising effect of the central heat of the earth, and which temperature was tropical.

414. Throughout the whole of this age, all that part of the earth to which geological research has been directed, was subject to the same slow and gradual undulations, as have been observed during the human period on the Scandinavian peninsula and elsewhere.

On seven different occasions, however, more violent geological perturbations took place, which swept from the earth and seas every living thing; and after these great catastrophes, when nature was tranquillised, Almighty power once more repeopled the land and the water, clothing the former with new vegetation.

FIRST CRETACEOUS PERIOD.

415. The great thickness of this stage, amounting at a mean estimate to 8000 feet, or above a mile and a half, shows that the duration of the period must have been considerable.

The composition of the stage includes the Purbeck beds, Hastings sand, Weald clay, and lower green sand of De la Beche, the Tilgate and Ashburnham beds of Mantell, and the Wealden or 15th group of Lyell.

The fauna, exclusive of Annulata, is presented in the following table:

FIRST CRETACEOUS PERIOD.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the First Cretaceous Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	2	2	0	2	2
	Reptiles	11	5	6	9	5
	Fishes	14	1	13	4	0
MOLLUSCA.	Cephalopods . .	15	7	8	1	1
	Gastropods . . .	30	9	21	0	0
	Lamellibranchia .	50	9	41	0	0
	Brachiopods . .	11	5	6	0	0
	Bryozoa	13	3	10	1	0
RADIATA.	Echinodermata .	21	10	11	3	2
	Polyparia . . .	27	12	15	7	6
	Foraminifera . .	11	4	7	0	0
	Amorphozoa . .	8	3	5	4	2
		213	70	143	31	18

One genus of crustacea (*Archæoniscus*) being added, gives the total number of genera known as composing the fauna 214, of which 70 had not existed in any previous period.

The two genera of birds called *Palæornis* and *Cimoliornis* were webfooted, and were the first of the order which had yet appeared. The *Archæoniscus* was of the order of isopodous crustacea.

Independently of the other classes, the number of species of mollusca and radiata alone catalogued and described is 851. An example of the mollusca is given in fig. 15.

416. Among the reptiles of this period were two of monstrous size, the *Iguanodon* and *Hylæosaurus*. The former, which has taken its name from some remote resemblance to the Iguana, a land-lizard of intertropical countries, had a body as massive as that of the elephant, measuring, when full grown, about 30 feet in length. It was herbivorous, feeding on the foliage of the ferns, cicadeæ, and conifers, which constituted the flora of the period.

The *Hylæosaurus*, scarcely less in magnitude, was also an herbivorous reptile.*

Besides these, the coasts abounded in tortoises; and reptiles of nine other generic forms, including the last of that strange class of flying reptiles, the *Pterodactyle*, which never reappeared on the earth after this period.

417. The land was richly clothed with vegetation. A catalogue of the plants has been published by M. Brongniart, who observes that the generic vegetable forms were nearly the same as in the

* Mantell—Wonders of Geology—p. 437.

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Jurassic age, the cicadeæ, however, being less numerous in relation to the ferns. The flora consisted principally of cryptogamous acrogenous plants, such as the arborescent ferns, the marsileaceous, and equisetaceous classes; of dicotyledonous gymnosperms, such as cicadeæ and conifers, and of many of doubtful classes.

SECOND CRETACEOUS PERIOD.

418. The composition of the second stage of the Cretaceous formation corresponds nearly with the 14th group of Lyell, including the Speeton clay of Yorkshire.

419. A generic summary of the fauna (excepting the Annulata), is given in the following table:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Second Cretaceous Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	0	0	0	0	0
	Fishes	3	1	2	0	0
MOLLUSCA.	Cephalopods . .	10	1	9	2	1
	Gastropods . . .	12	1	11	0	0
	Lamellibranchia .	31	0	31	0	0
	Brachiopods . .	3	0	3	1	0
	Bryozoa	3	0	3	0	0
RADIATA.	Echinodermata .	2	1	1	0	0
	Polyparia . . .	4	2	2	2	2
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	1	0	1	0	0
		69	6	63	5	3

420. The outlines of sea and land in Europe did not differ much from their configuration in the preceding period. An island was formed on the present site of the Alps, extending from Castellane near Digue, in the department of the Basses-Alpes, to the department of the Hautes-Alpes. See map, fig. 172.

421. The marine fauna differed but little from that of the preceding period, consisting of numerous cephalopods of singular forms (fig. 173, 174).

422. That the land was clothed with vegetation is proved by the numerous remains of wood found in the strata. M. Brongniart has described a pine of this period, the cone of which measured ten inches in length, and an inch and three quarters in diameter, found in the bed of the Marne near St. Didier.

THIRD CRETACEOUS PERIOD.

423. The identity of the tropical species found in extremely different latitudes, as, for example, in France and at Magellan's straits, lead to the same inference, as in former periods, of the general prevalence of an equatorial climate at all parts of the globe.

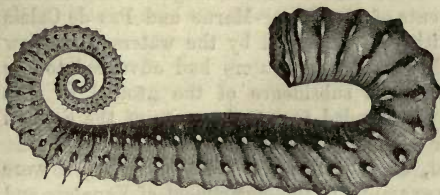


Fig. 173.—Ancyloceras Matheronianus.

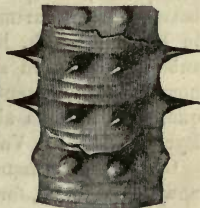


Fig. 174.

424. The convulsion which closed this period was, according to M. D'Orbigny, that by which the Fuegian chain of mountains in South America, the direction of which was N. 30°. W. and S. 30° E., was raised.

THIRD CRETACEOUS PERIOD.

425. The deposit of this period corresponds with the 13th or gault group of Lyell, including the dark blue marl of Kent, the Folkestone marl or clay, and Blackdown beds and green sand and chert of Devon.

426. A view of the generic forms of the fauna is given in the following table:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Third Cretaceous Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	1	1	0	0	0
MOLLUSCA.	Cephalopods	11	0	11	1	0
	Gastropods	27	3	24	1	1
	Lamellibranchia . . .	38	2	36	0	0
	Brachiopods	6	0	6	0	0
	Bryozoa	9	3	6	1	1
RADIATA.	Echinodermata	16	6	10	2	1
	Polyparia	2	0	2	1	0
	Foraminifera	9	2	7	0	0
	Amorphozoa	4	1	3	0	0
		123	18	105	6	3

Adding two genera of Crustaceæ, the total number of generic forms in this period hitherto discovered amounts to 125, of which 20 were new, and 105 revived.

427. The outlines of land and sea were similar to those of the last period, except on the borders of the Anglo-Parisian basin between the departments of the Haute-Marne and Pas de Calais in France, which, hitherto uninhabited by the waters, were now submerged, which shows that the waters had advanced to the north in consequence of a subsidence of the ground in that quarter. The sea also extended to certain parts of the Eastern Pyrenees and the Var not previously submerged.

On the other hand, certain parts previously submerged were now dry land, as, for example, in the department of Vaucluse and along the line of the Alps from Escagnolles in the Var to Grenoble, all of which were covered by the sea of the previous period.

428. The seas were inhabited by fishes, Crustacea, and Mollusca,

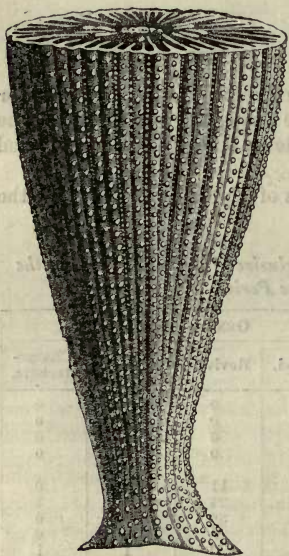


Fig. 175.—*Cyathina Bowerbankii*.

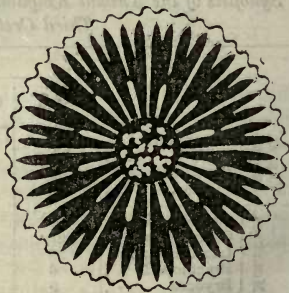


Fig. 176.

of numerous forms previously unknown. One of the *Polyparia* of this period is shown in figs. 175, 176.

FOURTH CRETACEOUS PERIOD.

No remains of terrestrial animals of this period have been found, and the only traces of vegetation are the remains of wood on the borders of the basins, with a few plants found at Lyme Regis and elsewhere.

429. Discordances in the strata indicate the convulsion which closed this period.

FOURTH CRETACEOUS PERIOD.

430. The fourth stage of the Cretaceous formation, called by M. D'Orbigny the Cenomanian, corresponds very nearly with the twelfth group, or upper green sand-stone of Lyell, including the Merstham fire-stone and the marly-stone, with chert of the Isle of Wight.

431. The generic forms of the fauna were as follow :—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fourth Cretaceous Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	2	1	1	1	1
	Fishes	3	1	2	0	0
MOLLUSCA.	Cephalopods . .	10	1	9	1	0
	Gastropods . . .	37	4	33	2	0
	Lamellibranchia .	50	4	46	2	0
	Brachiopods . .	11	1	10	2	0
	Bryozoa	24	8	16	5	2
RADIATA.	Echinodermata .	25	5	20	5	3
	Polyparia	29	16	13	7	5
	Foraminifera . .	14	7	7	3	3
	Amorphozoa . .	18	6	12	2	1
		223	54	169	20	15

Among these a new genus of reptiles called the *Raphiosaurus*, and one of fishes called *Otodus*, were included.

432. The shores of the seas of this period underwent some changes, owing probably to a subsidence of the ground. They advanced in Belgium as far as Tournay. They covered also that extensive surface included between Fecamp and Tours, and between Tours and Bourges, submerging ground which had remained dry land since the close of the Jurassic age. They covered also the whole extent of the Pyrenean basin, from the department of the Loire Inférieure to that of the Lot, and from

thence to Spain and Portugal, which had hitherto remained dry land. In the Mediterranean basin the waters were limited to certain points, and from the prevalence of identical species of organic remains, it is probable that they extended in one direction without interruption to Mount Lebanon in Syria, and in the other into Germany, extending over Westphalia, Saxony, Silesia, and Bohemia.

The continents were somewhat extended on some of the borders of the basins, especially on the east of the Anglo-Paris basin in France, and upon its west in England; but they lost extent by the advancement of the sea, as already explained, in Belgium. The land was also diminished by the submersion of a large tract in the west of France, extending from the Loire to Havre.

433. The seas were animated by numerous fauna, consisting of fishes, new forms of Mollusca among the Gastropods and Lamellibranchia, and a great quantity of Brachiopods which formed extensive submarine banks. There were also innumerable varieties of Bryozoa, Echinodermata, and above all, of Poly-paria. Of all the Cretaceous periods this was perhaps the most animated.

434. The shores of the seas were furnished with great varieties of marine plants—a catalogue of which with a description is due to M. Brongniart.

The terrestrial flora consisted principally of ferns, palms, cicadeæ, conifers, and dicotyledonous plants of uncertain families.

435. From what has been stated, it will be apparent that slow and local undulations of the ground, similar to what prevail at present in different parts of the earth, were common.

436. The convulsion which closed this period was that to which M. Elie de Beaumont ascribes the elevation of the system of Monte Viso (216), the direction of which is N.N.W. and S.S.E.

FIFTH CRETACEOUS PERIOD.

437. The fifth Cretaceous stage denominated Turonian by D'Orbigny, is identical with the eleventh or lower white chalk group of Lyell, including chalk without flints and chalk-marl. It is identical also with the upper plänerkalk of Saxony, and also with the chalk formation of Mantell.

438. The principal generic forms of the fauna of this period are shown in the following table :—

FIFTH CRETACEOUS PERIOD.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fifth Cretaceous Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	0	0	0	0	0
MOLLUSCA.	Cephalopods . .	5	0	5	1	0
	Gastropods . . .	18	3	15	0	0
	Lamellibranchia	35	0	35	0	0
	Brachiopods . .	9	3	6	2	1
	Bryozoa	3	0	3	0	0
RADIATA.	Echinodermata .	11	1	10	4	0
	Polyparia . . .	46	20	26	20	9
	Foraminifera . .	4	3	1	0	0
	Amorphozoa . .	4	1	3	1	1
		135	31	104	28	11

439. The outlines of the seas were nearly the same as in the former period; the shores, however, retired at several points, and especially in the Pyrenean basin, from the Loire Inférieure to La Vendée in the Mediterranean basin, upon all the known points, and in the chain of the Alps from La Malle in the department of the Var to Switzerland.

The continents underwent a corresponding change. The seas were very animated, as is evident from the vast number of Mollusca (fig. 14), and Echinodermata found upon the shores. They were also remarkable for numerous submarine reefs.

440. It would appear, from the fossil woods so frequently found, that the land was clothed with splendid vegetation, but owing to the destructive effects of the geological convulsion which followed, no complete remains either of plants or terrestrial animals have been found.

441. From the local absence of this fifth Cretaceous stage, it appears, that independently of several isolated points of land in France and Prussia during this period, a surface of dry land existed in Russia extending over 40° of longitude; another in North America measuring 30°; and others in South America and in India, which must have been above the surface of the waters, since no deposit corresponding with this stage appears there. Since all these regions were submerged in the succeeding period, it must be inferred that subsidence of the land over a great extent took place. This subsidence, according to M. D'Orbigny, extended from the torrid zone in the southern hemisphere to the 34° of latitude, and in the northern hemisphere to

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the 56°, or over the immense extent of 90° of latitude, being a quarter of the terrestrial globe. In longitude this subsidence was not less extensive, and is assigned by M. D'Orbigny as the immediate cause which terminated the fifth Cretaceous period.

SIXTH CRETACEOUS PERIOD.

442. The sixth Cretaceous stage corresponds with the tenth or upper white-chalk group of Lyell, including the white chalk with flints of the north and south downs. It is identical with the strata called by the Italians la Scaglia.

443. A generic summary of the fauna is given in the following table:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Sixth Cretaceous Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	1	1	0	0	0
	Reptiles	5	3	2	1	1
	Fishes	41	24	17	22	15
MOLLUSCA.	Cephalopods . .	12	0	12	10	0
	Gastropods . . .	42	5	37	8	0
	Lamellibranchia .	51	0	51	5	0
	Brachiopods . .	14	3	11	6	2
	Bryozoa	31	7	24	9	2
RADIATA.	Echinodermata .	34	11	23	19	6
	Polyparia . . .	23	7	16	12	5
	Foraminifera . .	25	13	12	7	4
	Amorphozoa . .	24	7	17	21	6
		303	81	222	120	41

Adding two genera of Crustacea not included in this table; it appears that the fauna hitherto discovered consisted of 305 genera, of which 81 were new, and 224 revived from former periods.

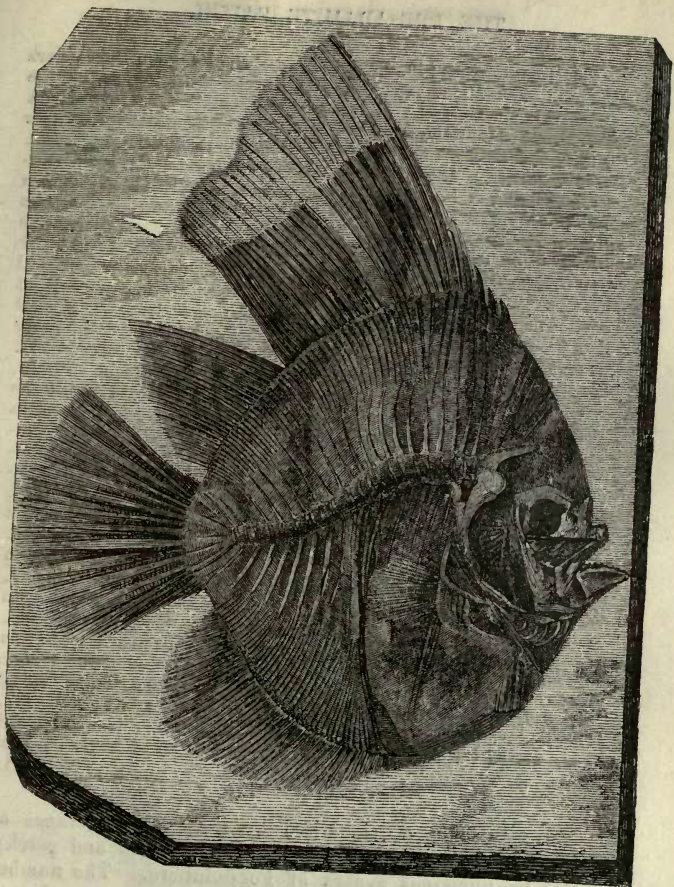


Fig. 184.—*PLATAX ALTISSIMUS*.

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CHAPTER VIII.

444. First appearance of fishes similar to the salmon and perch—specific forms of Mollusca and Radiata.—445. Great duration of the sixth Cretaceous period.—446. Great changes in the outlines of land and water.—447. Specimens of the fauna.—448. Flora and land animals

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—the Mosasaurus.—449. Close of the period. **SEVENTH CRETACEOUS PERIOD:** 450. Mineral character of the stage.—451. Synopsis of the animal kingdom.—452. Examples of the fauna.—**Tertiary Age.** 453. Origin of the name.—454. Classification of the strata—five stages—their nomenclature and thickness.—455. Complete series not found.—456. Section of the formation between the Vosges and Paris—discordances and isolation.—457. Palæontological distinction between the Tertiary and inferior formations.—458. The number of species in the Tertiary age.—459.—Distribution of the species among the stages.—460. General conclusions.—461. Outlines of land and water—D'Orbigny's map of France and England.—462. Great geographical changes from period to period.—463. Character of the fauna—great development of Mammifers.—464. Uniform prevalence of tropical climate.—465. Gradual and violent undulations of the land. **FIRST TERTIARY PERIOD.** 466. Mineral character of the stage.—467. Synopsis of the animal kingdom.—468. Great development of fishes.—469. Vast increase of land animals, including those of which the rhinoceros, otter, dog, ferret, and squirrel are types.—470. Creation of flat-fish.—471. The Mollusca—nummulites.—472. Whole mountains formed of these animals.—473. Vast duration of the period.—474. Terrestrial flora.—475. Outlines of land and water—Anglo-Parisian basin—form of its shores in France and England.—476. Pyrenean basin.—477. Mediterranean basin.—478. Its great extent towards the east.—479. Fresh-water lakes.—480. Close of the period. **SECOND TERTIARY PERIOD.** 481. Elevation of the Pyrenees—elevation of the tract of Bray in France, and of the Wealden in England.—482. Synopsis of the animal kingdom.—483. Specific forms of Mollusca and Radiata.—484. Creation of Cetacea, or whale forms.—485. Prodigious numbers of Miliolæ, of which the stone quarries of Paris are formed.—486. Marine flora—land animals, including the generic forms of which apes, bats, gallinaceous, predaceous, and climbing birds, serpents, rattle-snakes, baboons, and opossums are types.—487. Crocodiles and land tortoises—belemnites and nautili—terrestrial flora.—488. Outlines of land and water—division of Anglo-Parisian basin into two seas.

444. THIS period was signalised by the first appearance of fishes of the Cycloid and Ctenoid orders (salmon and perch), and also by numerous genera of Foraminifera. The number of species of Mollusca and Radiata alone which entered into the composition of this fauna was 1577, all of which were new to animated nature, and all of which disappeared at the close of this period.

445. The great thickness of the stage, measuring, as we have seen, 1000 feet, and the great number of species found in it, lead to the conclusion that this sixth period was one of the longest of the Cretaceous age.

446. The seas of this period underwent considerable changes both in France and England. In some parts their shores retired, leaving increased tracts of dry land, while in others, as in the department of La Manche in France, tracts hitherto dry were

SIXTH CRETACEOUS PERIOD.

submerged. Great changes were also produced at other points. Thus it was at the commencement of this period, that in consequence of a considerable subsidence of the land, the sea flowed over all Belgium as far as Maestricht, covering land which had remained dry since the close of the Palæozoic age. It was also during this period that the sea extended its limits from Snowdon to the Ural Mountains, over an extent of 40° of longitude. It also covered a surface of 30° upon the southern coast of South America. It covered also Chili in the western continent, and Pondicherry in the eastern. From the identity of the marine deposits, it may be inferred that the sea of this period extended without interruption from France to all those distant points and from the tropics to the 56° north, and the 34° of south latitude.

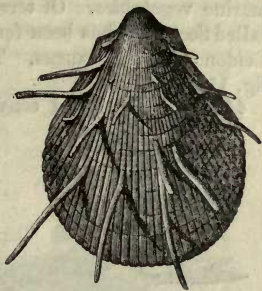


Fig. 177.—*Spondylus spinosus*.

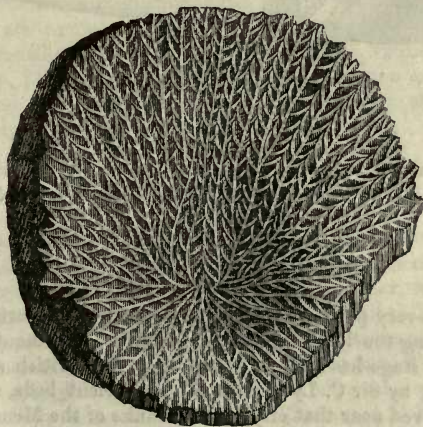


Fig. 178.—*Reticulopora obliqua*.

The land underwent changes corresponding with those of the seas, being everywhere augmented where the seas retired, and diminished where they advanced.

447. The Cycloid and Ganoid fishes prevailed in great numbers

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in the seas, which were also animated by an infinite variety of Mollusca—Gastropods, Brachiopods, Lamellibranchia (fig. 177), and Bryozoa (fig. 178).

448. The shores of the seas were abundantly furnished with marine vegetables. Of terrestrial animals, one genus of birds, called *Scolopax*, has been found: and of land reptiles, two genera, *Leidon* and *Mosasaurus*. The jaws of the latter are shown in fig. 179.

449. The geological convulsion which terminated this period,

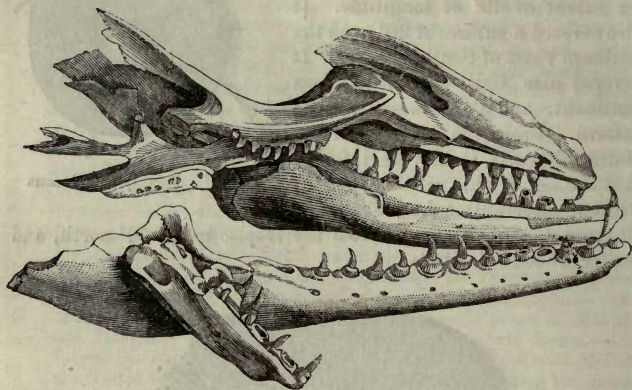


Fig. 179.—*Mosasaurus Camperi*.

according to M. D'Orbigny, was that which raised the chain of the Cordilleras of Chili, the direction of which is N. 5°. E. and S. 5°. W.

SEVENTH CRETACEOUS PERIOD.

450. In every point of view, this is the least important of the periods, being the last stage of the decadence of the Cretaceous age. This stage has no representative in the British strata. It is identified by Sir C. Lyell with the Maestricht beds, a group of strata observed near that city, on the banks of the Meuse, having the thickness of about 100 feet. It rests upon the ordinary white chalk and flints, which form the sixth Cretaceous stage, and contains fossils, which, according to Sir C. Lyell, are, on the whole, very peculiar, and all distinct from those of the Tertiary age, which immediately succeeded it.

451. The following is a general view of the fauna of this period, so far as the fossil remains show it.

TERTIARY AGE.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Seventh Cretaceous Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	0	1	1	0
	Fishes	?	?	?	?	?
MOLLUSCA.	Cephalopods . .	2	0	2	1	0
	Gastropods . . .	17	1	16	0	0
	Lamellibranchia	11	0	11	0	0
	Brachiopods . .	2	0	2	1	0
	Bryozoa	0	0	0	0	0
RADIATA.	Echinodermata .	4	1	3	1	0
	Polyparia . . .	8	0	8	5	0
	Foraminifera . .	0	0	0	0	0
	Amorphozoa . .	1	0	1	0	0
		46	2	44	9	0

452. Independently of some Saurians, fishes, Crustacea and Annelides, found among the fossils, sixty-six species of Mollusca and Radiata have been catalogued by M. D'Orbigny, of which only two are common to this and the preceding period. Of these, a considerable number, including the *Nautilus Danicus* (figs. 9, 10, 11), are found in this stage in Sweden as well as in France, and may be regarded as more especially characteristic of the closing period of the Cretaceous age.

The Tertiary Age.

453. At an early date in the progress of the science, the strata below the Jurassic formation were called primary, and the Jurassic and Cretaceous formations, taken together, were denominated secondary, having been obviously deposited from the seas of that era upon the former. Hence the most recently deposited group of strata resting upon the Cretaceous formation, and immediately subjacent to the diluvial and alluvial deposits of the human period, received the name of Tertiary, which, by general consent, they have retained, although subsequent discoveries have shown that the preceding deposits, instead of being resolved into two, are much more properly regarded as consisting of a greater number of distinct groups.

454. The strata composing the Tertiary formation have been very variously classed, and grouped in geological works. Sir Charles Lyell has divided them into three principal groups, which

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he calls Eocene, Miocene, and Pliocene. He divides the first into three, and the last into two subordinate groups, thus making the whole formation consist of six stages. M. D'Orbigny finds that a division into five stages is more in accordance with the distribution of the organic remains. The following are the names which he has given to the five strata, with their origin, and their estimated average thickness :—

No. of stage.	Name.	Origin.	Thickness.
V.	Sub-Apennine	Apennines	Feet 2000
IV.	Falunian . . .	Falun (conchiferous crag)	1000
III.	Tongrian . . .	Tongres	330
II.	Parisian . . .	Paris	3300
I. {	Suessonian or	Soissons	3300
	Nummulitic . }		
Total			9930

Although these estimates of thickness must be regarded as mere approximations, they will, nevertheless, be useful as exponents of the relative duration of the five periods into which the Tertiary age is divided. The total average thickness of this Tertiary formation would appear to be about 10000 feet, or two miles, the chief parts being occupied by the two lowest stages.

455. The complete series of stages can scarcely be found in any single locality, but, partially united, their order can be easily determined by comparing sections made in different places.

456. Fig. 180 represents a section from Vertus to Paris, being the continuation of the general section of the country from the Vosges to Paris, the first three divisions of which, commencing from the Vosges, have been already given in figs. 141, 152, and 170. In this section, the first three only of the stages, proceeding upwards, are included, being numbered 24, 25, and 26.

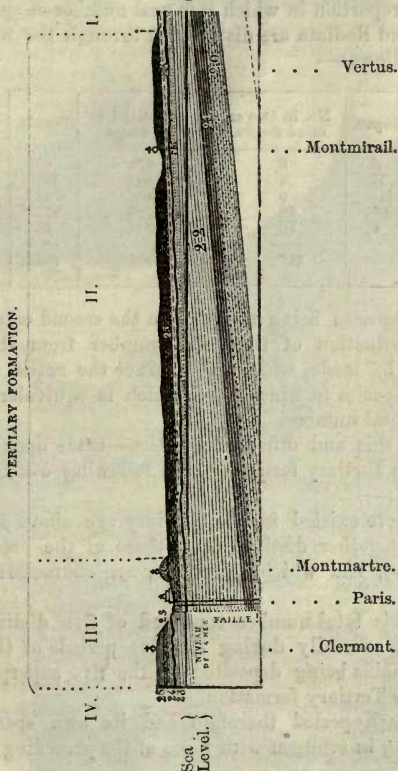
As in the preceding formations, the single stages are distinguished one from another, partly by discordance of stratification, but much more by what geologists call discordances of isolation ; that is, by the appearance of certain stages, and the absence of others. For example, while round the Anglo-Parisian basin the first of the Tertiary stages is deposited immediately upon the last of the Cretaceous; in other places many intermediate stages are wanting. Thus, near Orgon, in France, the first Tertiary stage is deposited upon the first Cretaceous, all the other six stages of the Cretaceous formation being absent. In like manner, in the department of the Aude, the first Tertiary stage is deposited upon the Palæozoic formation ; and in the department of the Var and the Lower Alps upon the Jurassic formation. In

TERTIARY AGE.

like manner, throughout the province of Touraine, the first and second Tertiary stages are absent, the third being deposited in different localities upon the Azoic, Palæozoic, the Jurassic, or the Cretaceous formations.

457. Palæontological considerations supply other distinctions between the Tertiary and inferior formations. Nearly 230

Fig. 180.



generic forms extinct at the close of the Cretaceous age, and not appearing in the Tertiary age, constitute a distinguishing characteristic between the two epochs. In like manner, at the commencement of the human period, 1324 new generic forms were created which had no previous existence, and which, not being present in the Tertiary age, supply a distinction between it and the human epoch.

THE PRE-ADAMITE EARTH.

458. The number of species of plants and animals of every order which lived in the Tertiary age, greatly exceeds that of any former period. The number of vegetable species found in the Tertiary strata exceeds 600, and that of Vertebrata and Annullata amounts to nearly 1500, while the number of Mollusca and Radiata, catalogued and described as belonging to this age, amounts to 6042.*

459. The proportion in which this vast number of specific forms of Mollusca and Radiata are distributed through the five Tertiary stages is as follows:—

Stages.	No. in two or more stages.	No. limited to each stage.	Totals.
I.	8	670	678
II.	8	1568	1576
III.	0	428	428
IV.	28	2726	2754
V.	83	523	606
	<hr/> 127	<hr/> 5915	<hr/> 6042

The same species being repeated in the second column, a corresponding deduction of the total number from the common species must be made, which will reduce the actual number of the common species to ninety-one, which is equivalent to $1\frac{1}{2}$ per cent. of the total number.

460. From this and other observations made upon the strata composing the Tertiary formation, the following conclusions have been adduced:—

1°. That there existed in the Tertiary age above 8000 species of animals, altogether distinct from those of the preceding and following ages, and which, therefore, are characteristic of the Tertiary age.

2°. That this total number consisted of five distinct groups, which existed severally during the five periods of the Tertiary age, their remains being deposited in the five superposed stages composing the Tertiary formation.

3°. That each period therefore had its own special fauna, having nothing in common with those of the preceding or succeeding periods.

4°. That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed $1\frac{1}{2}$ per cent. of the total number of species discovered.

461. The seas of this age in Western Europe consisted of four,

* *Predrome D'Orbigny*, vols. ii. and iii.

TERTIARY AGE.

three of which, the Anglo-Parisian, the Pyrenean, and the Mediterranean basins correspond with those of former epochs.



Fig. 181.—Map of France and England in the Tertiary Age. By M. D'Orbigny.

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The fourth, to which the name of Ligerian basin has been given, covered part of the western provinces of France, as indicated upon the map (fig. 181).

462. It must not be understood, however, that during the whole continuance of the Tertiary age, or even during any two periods of it, these seas maintained the same circumscription or corresponded exactly with the outlines given in this map. On the contrary, the geological convulsions which took place between period and period, produced such changes of level in the land as completely to derange the outlines of land and water. Thus the Anglo-Parisian basin not only changed its form and limits in different periods, but in one totally disappeared, while in the first periods of the Tertiary age the Ligerian basin had no existence. Previously to the convulsion in which the chain of the Pyrenees was elevated, the Pyrenean basin covered the ground upon which that range afterwards stood, but after their elevation its shores were driven northwards and its dimensions considerably reduced. These changes of the outlines of land and water will, however, be more clearly explained in the account we shall give of the successive periods of this age.

463. The most striking characteristic of the fauna of the Tertiary age, was the extraordinary development which took place among vertebrated animals. It was then indeed that the land was first peopled by those mammifers so remarkable for their proportions and characters, such as the *Anthracotheriums*, the *Palæotheriums*, the *Anoplotheriums* (fig. 182), the *Dinotheriums*, the *Toxodons*, the *Mastodons*, the *Smilodons*, the *Glyptodons* (fig. 183), the *Megatheriums*, the *Megalonix*, and many others. It was then also that the continents were first peopled by birds which would be pronounced colossal even beside the ostrich, and with salamanders as large as the present crocodile. Around this stupendous fauna was collected a flora on a proportionate scale. The seas were peopled by marine classes in a corresponding proportion, and almost as varied as in our own day.

464. The generic animal forms, peculiar to present tropical climates, being found distributed indifferently in all latitudes, it is inferred that a general tropical temperature, as in former periods, prevailed, and that consequently no isothermal lines or climatological distinctions existed upon the earth until the present period.

465. Numerous indications are also found among the geological phenomena, of the prevalence during this age of those slow and gradual undulations of the earth's crust which are still in progress in the north of Europe and elsewhere, independently of the more violent class of convulsions by which period was divided from period, fauna from fauna, and flora from flora.

FIRST TERTIARY PERIOD.

FIRST TERTIARY PERIOD.

466. The first Tertiary stage in its mineralogical characters corresponds with the lower part of the Eocene group of Lyell, the Nummulitic formation of Gras and other geologists, the Plastic clay of Dufresnoy, Elie de Beaumont, and Mantell, and the Woolwich sands of Morris.

467. After the general agitation produced by the geological convulsion which closed the Cretaceous age had subsided, a new fauna and flora were called into existence to people and clothe the earth. A generic synopsis of the former is produced in the following table:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the First Tertiary Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	6	6	0	0	0
	Birds	1	1	0	1	1
	Reptiles	2	0	2	0	0
	Fishes	91	83	8	34	34
MOLLUSCA.	Cephalopods . . .	3	2	1	0	0
	Gastropods	70	34	36	0	0
	Lamellibranchia . .	35	5	30	1	1
	Brachiopods	2	0	2	0	0
	Bryozoa	10	0	10	1	0
RADIATA.	Echinodermata . . .	23	13	10	4	3
	Polyparia	17	8	9	3	1
	Foraminifera . . .	8	3	5	0	0
	Amorphozoa	1	0	1	1	0
		269	155	114	45	40

With the addition of one genera of Crustacea (squilla), the total summary of the generic forms of animal life in this period will then be 270, of which 156 were now first created, and the remaining 114 revived from former periods.

468. This period was remarkable for the great development of fishes, of which 83 new genera were created. Of the Mollusca, the Gastropods were most developed, 34 new genera having appeared. The total number of species of Mollusca and Radiata described in this period amounts to 678, which, however numerous, are inferior in number to the same divisions in some former periods. Before the Tertiary age, some few traces of the existence of Mammifers were found, but with the exception of a few isolated bones, such traces everywhere consisted of foot-tracks.

469. The commencement of the Tertiary age was, however, more especially signalised by a prodigious accession to this highest

THE PRE-ADAMITE EARTH.

branch of the animal kingdom, six genera being created and named as follows:—

Anthracotherium, a genera of Pachydermatous animals, found in the lignite or brown coal in Italy, the name being a Greek compound, signifying *coal beast*.

Lophiodon, another Pachydermatous animal, allied to the Rhinoceros or Tapir, taking its name from a Greek compound, signifying *teeth*, formed like the hairs of a *mane*.

Lutra, a generic form of which the otter is the type.

Canis, a generic form of which the dog is the type.

Viverra, a generic form of which the ferret is the type.

Sciurus, a generic form of which the squirrel is the type.

470. The seas were enriched with a great number of animals hitherto unknown. The shores were animated by innumerable fishes, including many Pleuronectoids, or flat fish, which now appeared for the first time (fig. 184).

471. Among the multitude of Mollusca new to the world at this epoch, may be mentioned the Beloptera, Oliva, Tritons, Terebratulæ, &c. The Zoophytes and Foraminifera abounded, compensating by their prodigious numbers for the minuteness of their dimensions; but the class from which the period took its most prominent character was that of the Nummulites, an animal of a round flat form, resembling that of a coin, from which the name of the class is taken (figs. 185, 186, 187). These animals are technically described as chambered spiral univalve shells.

Fig. 185.

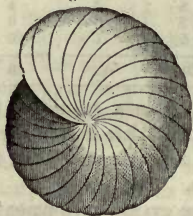


Fig. 186.



Fig. 187.



Nummulites planulata.

These Nummulites lived far from the coast, and their shells were deposited in layers of prodigious thickness upon the deepest bottoms of the seas.

472. At subsequent periods geological convulsions occurred, by which the conchiferous strata thus formed were forced upwards, so as to form mountain ranges. An example of such chains is presented in the Pyrenees, where entire mountains are found consisting of little else than the fossilised remains of these minute animals. It is a striking fact also, that it was of like materials that the Pyramids of Egypt were built.

FIRST TERTIARY PERIOD.

473. The great duration of this first Tertiary period may be judged from the fact, that these nummulitic strata have in some localities a thickness of several hundred yards. The marine flora of this period consisted chiefly of Cryptogamous Amphigenes, Algæ, and monocotyledonous Naiads.

474. The terrestrial flora consisted of Cryptogamous Acrogenes, such as Hepaticæ, ferns, Equisetaceæ or mares' tails, Characeæ, Palms, Conifers, and Taxineæ.

475. In comparing the geography of this period with that of the preceding, it will be seen that, while at some parts the seas are limited by the same shores, at others their outline is completely changed. Upon the northern and southern borders of the Anglo-Parisian basin, the shores lie within those of the Cretaceous age, leaving a band of ground, previously submerged, uncovered. On the south, the shores have retired still further, no traces of the deposits of this stage being found beyond the line which would pass through Montereau, Melun, Paris, Houdan, and Louviers. This basin extended in England, in an irregular direction S.W. and N.E., from Dorchester to Wells, passing through Dorsetshire, Wiltshire, Surrey, Berkshire, and Hertfordshire, in a direction which probably extended much further to the north over the ground now covered by the German Ocean.

476. In the Pyrenean basin the northern limits of the sea were nearly the same as in the Cretaceous period. It extended probably from the Atlantic Ocean to the Mediterranean, covering all the space upon which the Pyrenees now stand as well as part of Spain.

477. In the Mediterranean basin the sea entirely changed its place: Provence, which it formerly covered, was now occupied by fresh-water lakes, but the sea appeared above Grasse, in the department of the Var; its western shore extended W.N.W. to Castellane, and seemed to follow the line now occupied by the chain of the Alps to Annecy, and beyond that to Glaris.

478. Beyond these limits this sea extended to the east, over Sardinia, Italy, the Tyrol, part of Switzerland, and communicated probably with Egypt, the Crimea, the Caucasus, and from the slopes of the Ural to India. Corresponding changes took place on the land, a fresh-water lake existed at Rilly la Montaigne. On the north of the Pyrenean basin the land was uninterrupted from the Ocean to the Mediterranean.

479. A fresh-water lake covered the part of Provence between Orgon, Martignes, and Aix. These and other details may be easily followed on M. d'Orbigny's map (fig. 181), where the seas of this period are distinguished by the shading number 24.

480. The changes which took place in the outlines of land and water in consequence of the convulsion which closed the Cretaceous

THE PRE-ADAMITE EARTH.

age, and which preceded the first Tertiary period, will be clearly perceived by comparing those parts of the map (fig. 181), which we have here indicated, with the parts of the map (fig. 172, numbered 22.)

SECOND TERTIARY PERIOD.

481. The animal and vegetable world of the first period was swept away by the convulsion produced by the elevation of the chain of the Pyrenees, which was attended with a general perturbation of the whole surface of the globe. The date of this convulsion is identified with the first Tertiary period by the fact of the nummulitic strata which were deposited during that period being found dislocated along the entire extent of the Pyrenean range. The same dislocation elevated the tract of Bray in France and the country round Boulogne, both of which were submerged by the Anglo-Parisian sea. Parts of Surrey and Sussex in England, including the Wealden, were raised at the same time.

The second Tertiary stage includes the London clay of English geologists, the fresh-water and marine formation of Morris, a part of the eocene of Lyell, the blue clay of Bracklesham, the arenaceous limestone of Bognor of Mantell, and the calcareo-arenaceous system of Galeotti.

482. The following is the generic synopsis of this period :

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Second Tertiary Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	21	17	4	8	7
	Birds	11	10	1	2	2
	Reptiles	6	2	4	0	0
	Fishes	39	20	19	14	10
MOLUSCA.	Cephalopods . .	4	0	4	1	0
	Gastropods . . .	78	7	71	6	1
	Lamellibranchia .	57	9	48	3	3
	Brachiopods . . .	2	0	2	0	0
	Bryozoa	14	1	13	2	1
RADIATA.	Echinodermata .	18	5	13	6	3
	Polyparia	45	28	17	20	16
	Foraminifera . .	31	13	18	5	3
	Amorphozoa . . .	1	0	1	0	0
		327	112	215	67	46

With the addition of five genera of Crustacea, the total number of genera ascertained to have existed in this period was, therefore, 332, of which 116 appeared for the first time in the world.

SECOND TERTIARY PERIOD.

483. Independently of several hundred species of Vertebrata and Annulata, the fauna of this period included 1576 species of Mollusca and Radiata, which have been enumerated and described by D'Orbigny.

484. A great number of new animals abounded in the seas, the chief part of which consisted of new genera of fishes and Polypteria or Zoophytes. It was in this period that the class of Cetacea or marine mammals first appeared in the genera of the Dolphin and the Balænodon. Among the Crustacea the generic forms of crabs were first presented.

485. Of the Zoophytes and Foraminifera, the Miliolæ, characterised by its multilocular shell, and taking its name from *milium*, the Latin word for millet seed, prevailed in numbers so enormous, as to form those strata of stone of which nearly the whole of the city of Paris is built. It is a curious circumstance, therefore, that one of the greatest cities of the world should owe its fabrication to the original industry of minute animals which lived countless ages before the creation of man. The prodigious multitude of these minute beings, which must have existed to produce the quarries of Paris alone, not to mention similar ones which exist elsewhere, may be imagined when it is stated that, taking into account the weight of these shells, it has been calculated that a cubic inch of stone must be composed of not less than two thousand millions of them.

486. The marine flora of this period was generically similar to that of the last, differing, however, altogether in the species. Numerous land animals appeared for the first time, among which may be mentioned the following,—*mammifers*, apes and bats; *birds* (fig. 188), predaceous climbers and gallinaceous; *reptiles*,

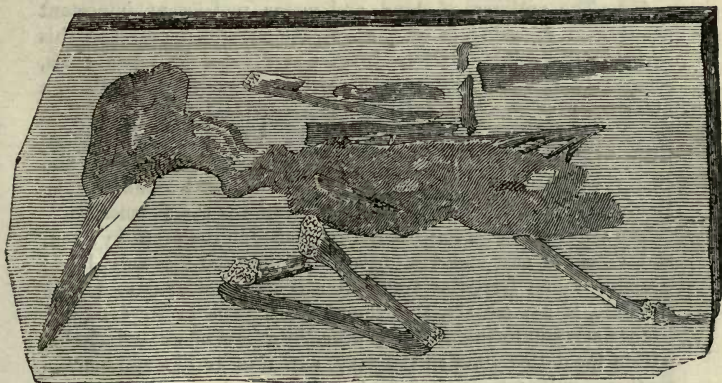


Fig. 188.—Fossil in the Gypsum of Montmarire.

serpents. The forests of France and England abounded in generic forms, of which baboons, rattlesnakes, and opossums are the living types.

The plains nourished Pachydermatous animals, called Paleotherium, Anaplotherium, &c. (fig. 189).

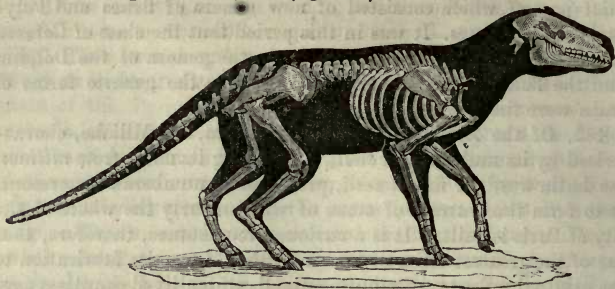


Fig. 189.—Common Anaplotherium.

487. The gigantic saurians of former periods had altogether disappeared in the Cretaceous age, but a large race of crocodiles and land and sea tortoises succeeded them. The Belemnites and their chambered shells had disappeared from the seas, the Nautilus alone remaining.

The cicadeæ totally disappeared from the flora, and new conifers, with dicotyledonous plants and palms, appeared in the centre of Europe,—plants which at present have receded into Africa, showing that the mean temperature of the continent then corresponded to that which at present prevails in Lower Egypt.

488. The outlines of land and water underwent important changes in consequence of the convulsions which preceded this period. The Anglo-Parisian basin was divided into two gulfs, completely separated, by a tract passing through its middle in a direction nearly east and west. The two separate basins thus formed are marked on the map by the shading 25. The northern basin in France covered part of Belgium, including Brussels and Ghent, with an angle of France, which included Dunkirk. In England it included London and the mouths of the Thames.

The southern basin was limited in France on the north by Laon, and extended east and west between Havre and Epernay, being bounded by an irregular line. It may be considered as highly probable, if not certain, that the northern gulfs in England and France communicated with each other by a tract of water included within the dotted lines on the map, and that in like manner the southern gulfs were united by a tract of water extending from Havre to the Isle of Wight.

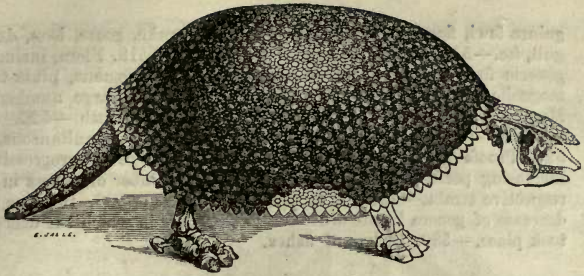


Fig. 183.—GLYPTODON CLAVIPES.

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CHAPTER IX.

489—490. Great change in the Pyrenean and Mediterranean basins.—491. Land and water in the United States.—492. Effect of the elevation of the Pyrenees.—493. General prevalence of tropical climate.—494. Great change in the Mediterranean basin.—495. Sketch of part of Western Europe by Elie de Beaumont. **THIRD TERTIARY PERIOD.** 496. Mineral character of the stage.—497. Convulsion which preceded the period.—498. Outlines of land and water.—499. Marine fauna and specific forms of Mollusca and Radiata. **FOURTH TERTIARY PERIOD.** 500. Mineral character of the stage.—501. Synopsis of animal kingdom.—502. Specific forms of Mollusca and Radiata.—503. Convulsion which preceded the period—Disappearance of Anglo-Parisian sea—Ligerian basin.—504. Pyrenean basin.—505. Marine fauna.—506. Enormous increase of land animals, including the generic forms of the bear, the cat, the weasel, the seal, the mouse, the beaver, the rhinoceros, the tapir, and the stag.—507. Great increase of reptiles and fishes, including snakes, frogs, salamanders, perch, herring, and carp.—508. Flora, including the generic forms of various conifers; birch, alder, oak, beech, elm, fig, plantain, poplar, laurel, sloe-tree, maple, red jasmin, madder.—509. Uniform tropical climate. **FIFTH TERTIARY PERIOD.** 510. Mineral character of the stage.—511. Synopsis of the animal kingdom.—512. Outlines of land and water.—513. Elevation of the Western Alps—its effects.—514. Map of France by M. Elie de Beaumont.—515. Marine animals, including the generic forms of gudgeon, pike, loach, blay, and tench.—516. Terrestrial fauna including the megatherium, megalonyx, mylodon, and mastodon, and the generic forms of the elephant, hippopotamus, camel, giraffe, and stag.—517. Birds of the generic forms of the vulture, eagle, swallow, woodpecker, chat, anabate, lark, mothhunter, cuckoo, parrot, pheasant, common fowl,

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guinea fowl, flamingo, horned owl, rail, corncrake, goose, loon, duck, gull, &c.—518. Fossil salamander of Oeningen.—519. Flora, including generic forms of liquidamber, willow, myrtle, anemone, plum-tree, magnolia, holly, rhododendron, and azalea.—520. Large numbers of Mammifers.—521. Bone caves—cave of Gaylenreuth.—522. Retrospect.—523. Was creation at each period simultaneous.—524. Proofs in the affirmative.—525. Was there a progressively increasing perfection of organisation.—526. Number of orders in the respective strata.—527. Of genera in the orders.—528. Increase and decrease of genera in the orders.—529. Orders in which the decrease took place.—530. Orders of fishes.

489. GREATER changes still were produced, as indeed might be expected, in the Pyrenean basin. While its northern shores remained nearly the same, the southern limits were altogether changed. The sea, which in the preceding period covered all the ground upon which the Pyrenees stand, extending over part of Spain, was now driven back to the north, and occupied only a very small basin near Bordeaux, marked 25 on the map.

490. The same cause produced a considerable change in the shores of the Mediterranean basin, which no longer communicated with the Pyrenean basin, its western shores being driven back towards the east. It is probable that its western shores commenced near Nice, passing near Faudon and St. Bonnet, the site of the High Alps, from which, however, that chain had not yet arisen. From thence the shores of this sea were continued to Bex in Switzerland, where all traces of them are lost.

491. During this period, a considerable tract of the United States, extending from 31° to 39° lat., which had been raised above the waters since the end of the Cretaceous age, became submerged, so that the sea probably extended without interruption from Paris to the southern part of North America.

492. Corresponding changes took place in the land by the elevation of the chain of the Pyrenees, which presented a barrier to the progress of the ocean, and which left high and dry not only the mountain range itself, but also the interval included between that and the central plateau of France, so that Languedoc and Provence, and the surrounding country, formed one great continent.

493. The appearance of marine species identical with those deposited in the Anglo-Parisian basin in the seas by which the southern states of America were submerged, and the discovery of apes, rattlesnakes, and generic forms of marine animals and plants, proper to warm climates in all parts of Europe, and in the Isle of Sheppey, in England, prove that, at this epoch,

SECOND TERTIARY PERIOD.

the temperature of the present equatorial regions prevailed generally throughout Europe.

494. During this period, the Mediterranean basin was reduced to some small patches of water, which appeared in the Savoy, and in the region upon which the French Alps now stand. These are marked upon the map by the number 25.

495. Before the geology of Western Europe, in relation to this age, was submitted to the elaborate analysis of M. D'Orbigny, from which the details explained above have resulted, M. Elie de Beaumont published a map of its geography during this period, of which we give a reduction in fig. 190.

It will be seen that, according to this, the Anglo-Parisian



Fig. 190.—Map of Western Europe during the Second Tertiary Period.

basin was not inferred to be divided into two separate gulfs, as above described, but an insular tract was supposed to be formed around the country of Bray in France, and another around the Wealden in England.

The basin was assumed by M. Elie de Beaumont to extend between Paris and the Lizard Point, Cambridge and Maestricht. The Pyrenean basin is represented as limited between Bordeaux and Dax. It is probable, however, that the more recent

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geological researches in these regions have supplied data which have rendered the map of M. D'Orbigny the more exact.

THIRD TERTIARY PERIOD.

496. The strata deposited during this period, according to M. D'Orbigny, correspond with the middle *terrain tertiaire* and *grès de Fontainebleau* of MM. Dufresnoy and Élie de Beaumont, the Tongrian, Rupelian, and Bolderberg strata of M. Dumont, the Molasse of Switzerland, the Faluns bleus of M. Grataloup, and, in fine, with the fifth group of M. D'Archiac.

497. The second Tertiary period was closed by the convulsion which raised the system of Corsica and Sardinia of M. Elie de Beaumont. Upon the re-establishment of tranquillity, a new fauna was created, consisting of 428 species of Mollusca and Radiata, independently of the vertebrated and annulated classes.

498. The outlines of land and sea underwent several changes, the results of which will be seen on the map, the seas during this period being indicated by the shading marked 26*a*, fig. 181. The Paris basin was limited to a space round Paris, between Provins and Evreux, east and west. The Pyrenean basin covered the space similarly indicated and shaded, a tract of dry land, however, remaining to the N.W. of Blay. In Belgium, the seas advanced to the N.E., as far as Limbourg, in the neighbourhood of Maestricht.

499. The marine animals of this period, though generically identical with those of the succeeding one, were, nevertheless, specifically distinguished from them. This distinction has not, however, been clearly indicated, except in the case of the Mollusca and Radiata, 428 species of which M. D'Orbigny has identified with the deposits of this period. The flora included nearly the same generic forms as in the preceding epoch.

FOURTH TERTIARY PERIOD.

500. The strata deposited in this period, according to D'Orbigny, include part of the middle Tertiary and Falunian of MM. Dufresnoy and De Beaumont, the Molasse, Falunian and Crag of M. Cordier, the superior order of Conybeare, and the Miocene and Suffolk and Norfolk Crag of Sir C. Lyell.

501. The following is the generic summary of the fauna, which, however, includes a certain number of genera of the Vertebrates peculiar to the third stage.

FOURTH TERTIARY PERIOD.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fourth Tertiary Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	57	47	10	27	23
	Birds	7	4	3	0	0
	Reptiles	13	7	6	3	2
	Fishes	28	7	21	1	1
MOLUSCA.	Cephalopods . .	3	1	2	2	1
	Gastropods . . .	97	20	77	1	1
	Lamellibranchia	64	6	58	2	0
	Brachiopods . .	8	1	7	0	0
	Bryozoa	20	5	15	3	2
RADIATA.	Echinodermata .	23	6	17	2	1
	Polyparia	45	15	30	16	6
	Foraminifera . .	42	14	28	3	2
	Amorphozoa . .	1	0	1	0	0
		408	133	275	60	39

With the addition of fourteen genera of Crustacea, it appears, therefore, that this fauna consisted of 422 genera, of which 133 were new, and the remainder revived from preceding periods.

502. Independently of several hundred species of Vertebrata and Annulata, 2754 species of Mollusca and Radiata proper to this period have been catalogued and described.*

503. The third period was closed, and the present preceded by the dislocation which produced the system of the Isle of Wight, of the Tatra, of the Rilodagh, and of Mount Hæmus, as shown by M. Élie de Beaumont. After the re-establishment of tranquillity, the outlines of sea and land had undergone considerable changes. The water by which the Anglo-Parisian basin had never ceased to be submerged since the Triassic age, retired, and left all that region dry land. A new sea, however, was formed in the west of France, to which the name of the Ligerian basin has been given by M. D'Orbigny, and the limits of which are indicated on the map by the shading marked 26 *b*, fig. 181. The deposit left by this basin was, however, by a subsequent convulsion, broken into patches, so that, at the present time, it does not present one continuous stratum.

504. The Pyrenean basin was contracted within the limits marked on the map 26 *b*, fig. 181. The Mediterranean basin under-

* *Prodrome D'Orbigny*, vol. iii. p. 25 *et seq.*

went a complete change of form. It now submerged a vast surface, which was previously dry land, included between Montpelier and a tract to the west of Marseilles, extending on the north into the departments of the Gard and the Drôme. It extended also to the N.E. as far as the tract upon which the Lower Alps stand. Another arm of this sea turned to the N.N.E., covering part of Savoy and Switzerland, and extending probably to Vienna and still further in that direction. Thus three seas were still found in the west of Europe—the Ligerian basin taking the place of the Anglo-Parisian basin. In England, the Anglo-Parisian basin was limited to Suffolk and Norfolk, where it covered the whole coast, and it probably extended from thence across the Channel into Belgium, covering the land around Antwerp.

505. The seas during this period were peopled by numerous animals unknown to any anterior epoch. Not less than 89 marine genera appeared for the first time, among which the Gastropods amounted to 20, and the Foraminifera to 15. Among the Crustacea which now first appeared in the seas, were included the generic forms of which the Hermit crab and the Lobster are types.

506. But it was by its land animals that this period, compared with all former ones, was more especially remarkable. It appears by the table, that of the 57 genera of Mammifers ascertained to have lived in this period, 47 had never before existed. Of these genera a great number, remarkable either for their magnitude or their peculiar forms, have become extinct, among which may be mentioned *Palæomys*, *Macrotherium*, *Dinotherium*, fig. 191, *Toxodon*, and *Mastodon*. Among the forms which



Fig. 191.—*Dinotherium giganteum*.

have survived, we find living types in the bear, the cat, the weasel, the seal, the mouse, the beaver, the rhinoceros, the tapir, and the stag.

FIFTH TERTIARY PERIOD.

507. Among the reptiles which now appeared for the first time were generic forms, whose types are snakes, frogs, and salamanders, and among the fishes, those of which the types are the perch, the herring, and the carp, fig. 192.

508. The flora of this period included Amphigamous cryptogamia (Algæ and mushrooms), Acrogenous cryptogamia (Mosses and ferns), Monocotyledons, Dicotyledonous gymnosperms (numerous conifers), Dicotyledonous angiosperms (birch, alder, oak, beech, elm, fig, plantain, poplar, laurel, rose-tree, acacia, sumach, nut-tree, sloe-tree, maple, red-jasmine, madder.)

509. The presence in all the European seas of species, both

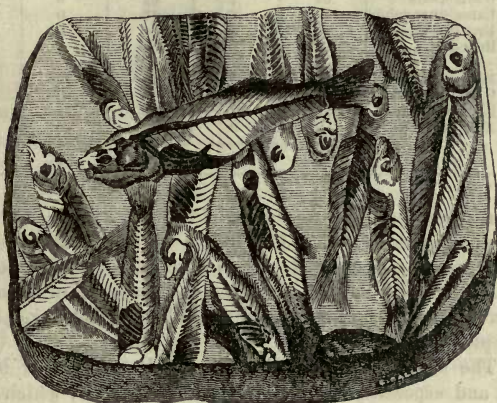


Fig. 192.—*Lebias Cephalotes*. Cyprin (Carp).

animal and vegetable, now peculiar to the Torrid Zone, proves that there prevailed, in this period as in the former, in France, England, and Germany, and probably in all other parts of the globe, a uniform temperature similar to that which now characterises the tropics. Climatological lines had not therefore yet existed.

FIFTH TERTIARY PERIOD.

510. The strata deposited in this period corresponded with the older Pleiocene of Sir C. Lyell.

511. The following is a generic synopsis of the fauna, with the exception of three genera of Crustacea.

THE PRE-ADAMITE EARTH.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fifth Tertiary Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers . . .	72	42	30	33	25
	Birds	29	26	3	1	1
	Reptiles	14	7	7	5	5
	Fishes	16	8	8	3	1
MOLLUSCA.	Cephalopods . .	1	1	0	0	0
	Gastropods . . .	64	2	62	0	0
	Lamellibranchia	46	2	44	0	0
	Brachiopods . .	4	0	4	0	0
	Bryozoa	8	0	8	1	0
RADIATA.	Echinodermata .	14	0	14	4	0
	Polyparia . . .	8	0	8	3	0
	Foraminifera . .	29	3	26	1	0
	Amorphozoa . .	0	0	0	0	0
		305	91	214	51	32

Of the Mollusca and Annulata alone 606 species have been catalogued and described. The fourth or Falunian period, as M. D'Orbigny has named it, was closed, and the fifth or sub-Apennine preceded by the geological convulsion, in which the Western Alps burst through the terrestrial crust and were elevated to their present relief.

512. The seas had again completely changed their beds in Europe, and especially in France. The three seas, which in the preceding period submerged the Ligerian, Pyrenean, and Mediterranean basins were now completely dried up, none remaining except small patches of water on the borders of the Mediterranean, in the departments, in the East Pyrenees, and in the Herault, near Montpellier. It appears, therefore, that in France land and water now assumed very nearly the forms which they possess at present, but in Piedmont the province of Asti was still submerged, as well as part of Italy, a tract round Vienna, and a great part of Eastern Europe.

513. Corresponding changes took place in the land. Switzerland, Savoy, the French departments of the Jura, the Ain, the Isère, the Higher Alps, the Lower Alps, the Drôme, Vaucluse, and the Bouches du Rhône, which had been severally to a greater or lesser extent submerged, during the Jurassic and Cretaceous ages, and during the previous periods of the Tertiary age, were now raised above the waters, and formed part of the general continent.

FIFTH TERTIARY PERIOD.

514. Although the western part of Europe, including France and part of Switzerland, were no longer submerged by the sea, sheets of fresh water existed in certain places. Thus, according to M. Beudant, a lake existed in France, extending north and south from Langres to Valence, fig. 193, and a similar one in Provence, between Sisteron and Verdon. The channel of Alsace, also, according to this geologist, still communicated with the ocean, and that of Piedmont, commencing from Nice and Genoa, was connected with the seas which washed the Apennines.

515. The seas of this period were peopled with the same generic forms as in the preceding, with the addition, however, of some new genera of fishes, such as the *Gobius* (gudgeon), *Esox* (pike), *Cobitis* (loach), *Aspius* (blay), and *Tinca* (tench).

516. The terrestrial fauna included a vast variety of forms, remarkable by their proportions and characters. Among the Mammifers were the *Glyptodon*, fig. 183, *Megatherium*, fig. 194, *Megalonyx*, *Mylodon*, fig. 195, and *Mastodon*, all of which are extinct. Among the genera which have since reappeared under other specific forms were elephants, fig. 196, hippopotami, camels, giraffes, horses, stags, fig. 197, p. 145, armadilloes, fig. 198, and sloths.

517. Among the birds were included genera of which the following are types, the vulture, eagle, swallow, woodpecker, chat, annabate, lark, moth-hunter, cuckoo, parrot, pheasant, common fowl, guinea-fowl, flamingo, horned-owl (*hibou*), rail, cornerake, goose, loon, duck, gull, grabe.

518. Among the reptiles of this period must especially be noticed the celebrated gigantic Salamander, fig. 199, found in the lacustrine limestone of Eningen. The first specimen of this fossil which was discovered obtained much notoriety from having been described as a human skeleton, under the fanciful name of *Homo diluvii testis*—a man who was witness of the deluge. Cuvier examined this specimen, and ascertained it to be the remains of a species of aquatic salamander. Other specimens of

Fig. 193.



THE PRE-ADAMITE EARTH.

the same fossil have been found which measured nearly five feet in length.

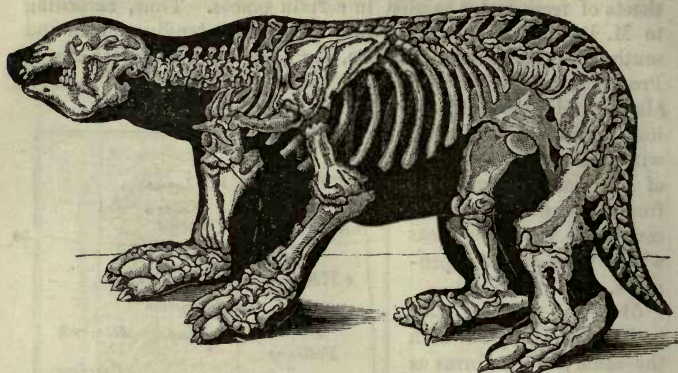


Fig. 194.—*Megatherium Cuvieri*.

519. To nourish the enormous herbivorous animals, which covered the land in such numbers from Italy to the Frozen



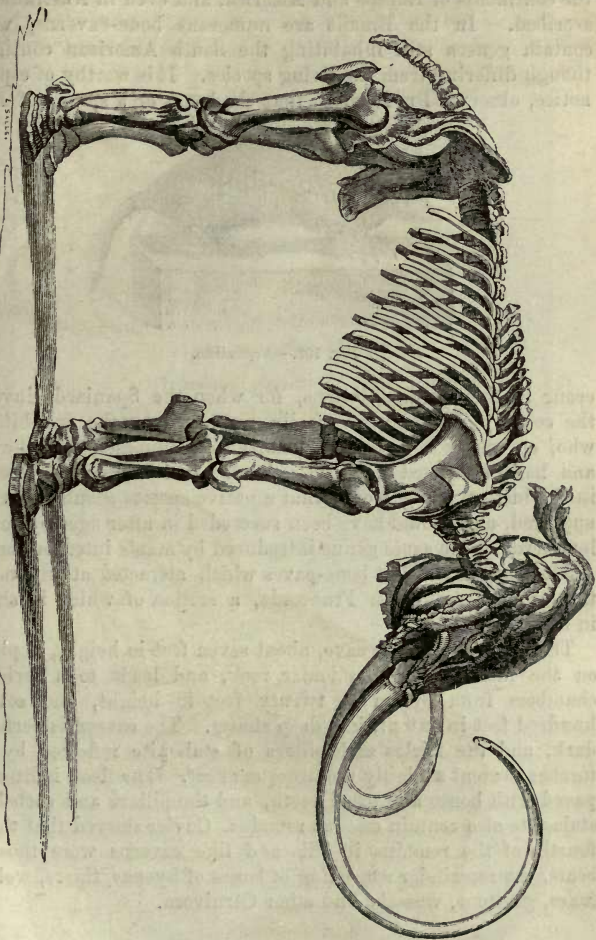
Fig. 195.—*Mylodon robustus*.

Ocean, and which at present are found only in those tropical

FIFTH TERTIARY PERIOD.

regions clothed with the richest vegetation, nature presented everywhere during this period the most varied and exuberant flora, which included nearly all the vegetable forms enumerated in

Fig. 106. — *Elephas primigenius*, or the Mammoth an animal of the Tertiary Age.



the preceding period, with the addition of numerous others, among which may be mentioned liquidamber, willow, myrtle, anemone, plum-tree, magnolia, holly, rhododendron, azalea, &c.

520. It is to this geological period, that the prodigious numbers of Mammifers found in the strata of the Pampas of Buenos Ayres, and in the caves which are scattered in such vast numbers over the continents of Europe and America, and even in Australia, are ascribed. In the Brazils are numerous bone-caverns, which contain genera still inhabiting the South American continent, though differing from the living species. It is worthy of especial notice, observes Dr. Mantell, that the bones of a species of horse

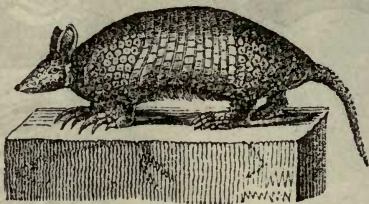


Fig. 198.—Armadillo.

occur in these accumulations, for when the Spaniards invaded the country, horses were wholly unknown to the inhabitants, who, on seeing a Spaniard on horseback, supposed that the man and horse composed a single animal. It is a marvellous event in the history of the world, that a native species should have disappeared, and should have been succeeded in after ages by countless herds of the same genus introduced by man's intervention.

521. One of the first bone-caves which attracted attention was that of Gaylenreuth in Franconia, a section of which is shown in fig. 200.

The entrance of this cave, about seven feet in height, is placed on the face of a perpendicular rock, and leads to a series of chambers from fifteen to twenty feet in height, and several hundred feet in extent, in a deep chasm. The cavern is perfectly dark, and the icicles and pillars of stalactite reflected by the torches present a highly picturesque effect. The floor is literally paved with bones and fossil teeth, and the pillars and corbels of stalactite also contain osseous remains. Cuvier showed that three-fourths of the remains in this and like caverns were those of bears, the remainder consisting of bones of hyenas, tigers, wolves, foxes, gluttons, weasels, and other Carnivora.

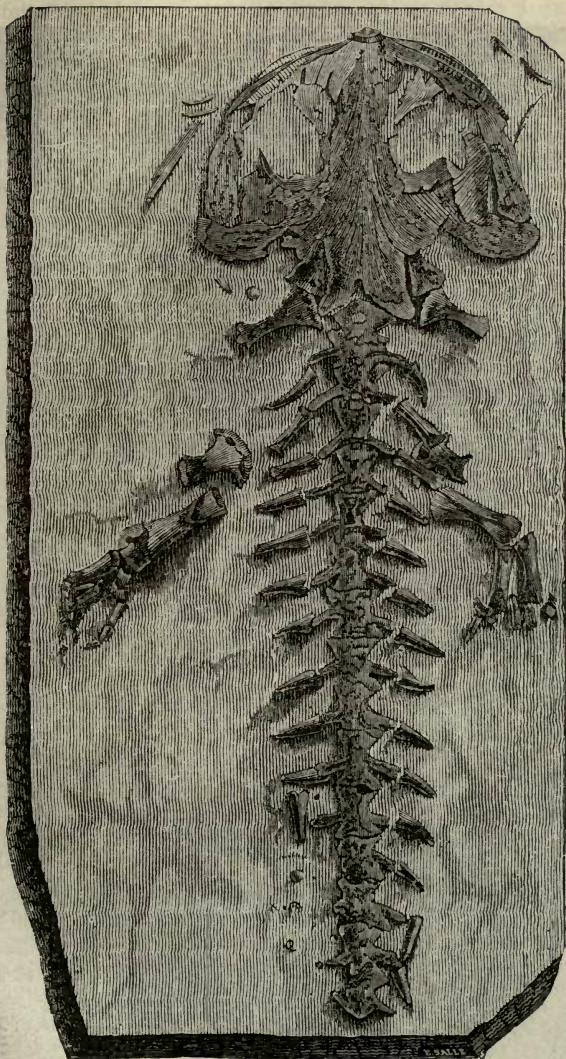


Fig. 199.—Fossil Salamander (*Andrias Scheuchzeri*).

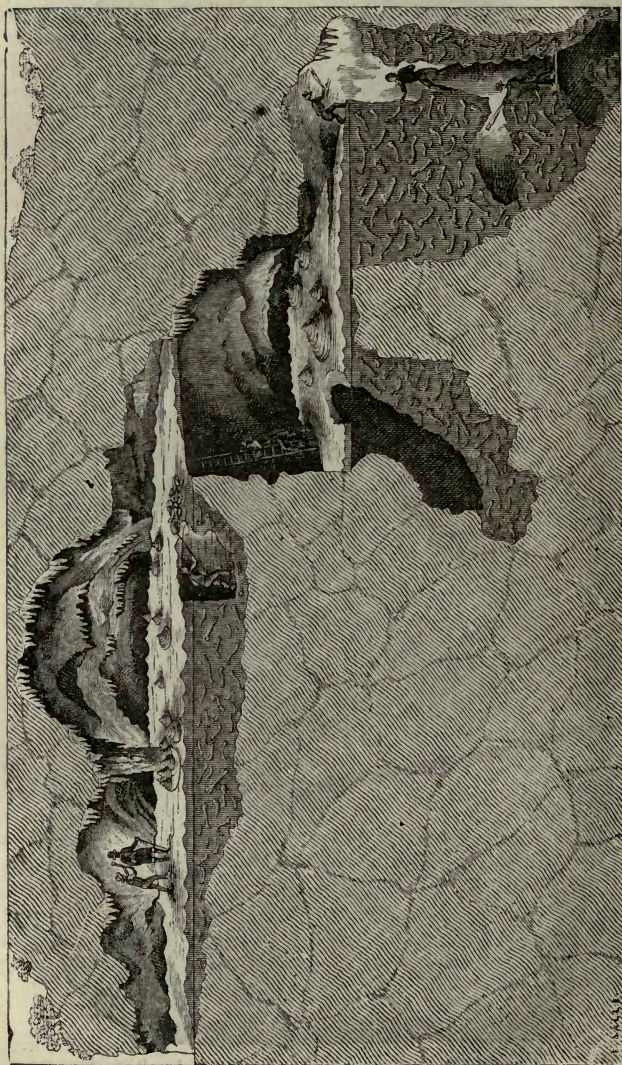


Fig. 200.—Section of the Bone Cavern of Gaylenreuth, Franconia.

RETROSPECT OF PRE-ADAMITE AGES.

RETROSPECT OF THE PRE-ADAMITE AGES.

522. Upon a review of the history of the earth previous to the appearance of the human race and its contemporary fauna and flora, as briefly sketched in the preceding pages, several considerations of high interest respecting the progressive development of organic life upon it present themselves.

Naturalists have grouped the animal world into the 20 classes indicated in the table given in (244), and have subdivided these classes into 77 orders. Each of these 77 orders is again resolved into a certain number of generic forms.

It will be matter of obvious interest to inquire in what manner the author of nature has proceeded in the work of creation, first, in considering each act of creation in itself, and independently of the others; and secondly, in comparing one with another the successive creations described in the preceding pages.

523. Were all the forms of organic life, which existed upon the earth at any one epoch, called simultaneously into being? The habits and economy of animals answer this question. In relation to their modes of nourishment they may be resolved into two classes: the first, herbivora, consisting of those which feed on vegetables; and the second, carnivora, of those which feed either partially or exclusively on other animals.

It is clear, then, that the creation of the vegetable world must, in each case, have either preceded or have been simultaneous with that of the herbivora, since a class of animals could not be created without a provision of a food of suitable quality.

For a like reason the creation of herbivora must either have preceded or been simultaneous with that of carnivora.

524. That all parts of the earth were simultaneously peopled, not only at the first creation which took place upon it, but at all succeeding ones, is proved by the fact that the same animal and vegetable forms are found deposited in the same strata in all parts of the earth. The animal forms, for example, preserved in the Palæozoic strata of Europe are identical with those found in the corresponding formation in all parts of the world, however distant from each other, and the same is true of the Triassic, the Jurassic, and all the other groups of strata.

525. The second question, whether creative power manifested itself by a progressive development of organised forms, may be considered either with relation to orders or generic forms.

Of the seventy-seven orders of animals, an obviously increasing progression of development will be apparent on comparing age with age.

526. The number of orders of which examples are found deposited in the strata are as follows :—

Palæozoic formation	31	Cretaceous	41
Triassic	21	Tertiary	71
Jurassic	41	Existing period	77

These figures show that the orders of animals are in constantly increasing progression. The exception presented by the Triassic group may probably be explained by the want of sufficient observation of its organic remains.

527. This constant increase does not prevail with the genera. In each period each order consisted of a certain definite number of genera. Now, on comparing the number of genera of which each of these orders consisted, from period to period, it will be found that while some continually increased, others having increased up to a certain date, attained their maximum, and then decreased, and that the decrease has continued to the present time.

528. Of the seventy-seven orders, it has been found by comparison of the organic remains of the successive periods, that sixty-three have had a continually increasing number of genera from their first appearance to the present epoch, but that the numbers of the genera of the other fourteen respectively after increasing to a certain period, then decreased, and that this decrease continued.

529. Six of these fourteen orders acquired their greatest generic development in the Palæozoic period. These six consisted of two orders of Fishes, one of Crustacea, two of Mollusca, and one of Radiata.

530. The two orders of Fishes are those denominated by naturalists the *placoids* and the *ganoids*. Of the former the *shark* and the *ray*, and of the latter the *sturgeon*, are living examples.

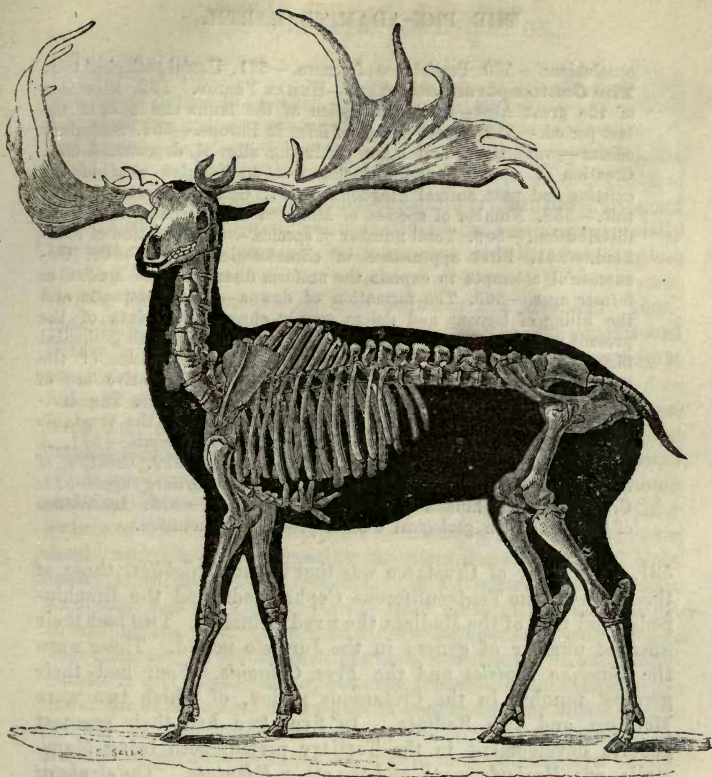


Fig. 197.—CERVUS MEGACEROS CUVIERI.

THE PRE-ADAMITE EARTH.

CHAPTER X.

531. Examination of orders.—532. Relative numerical proportion.—533. No progression discoverable in these.—534. Examination of generic development.—535. Similar result.—536. In the Radiata and Mollusca.—537. Annulata.—538. Vertebrata.—539. No progress indicated.—540. Organs of ancient animals.—541. Examination in relation to respiratory organs.—542. Lower divisions.—543. Branchial respiration.—544. No essential change.—545. No progression observable.—546. Tracheal respiration.—547. Pulmonary respiration.—548. Composition of atmosphere unchanged.—549. General

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conclusions.—550. Persistence of genera.—551. Useful geological test. **The Contemporaneous Age.**—HUMAN PERIOD. 552. Elevation of the great Alps—total destruction of the fauna and flora of the last period.—553. Great change of form in Europe.—554. Secondary effects—vast rivers and lakes producing alluvial deposits.—555. Creation of a new fauna and flora.—556. Tabular view of the existing and past animal kingdoms.—557. General inferences from this.—558. Number of species of Mollusca and Radiata, and their distribution.—559. Total number of species.—560. Creation of mankind.—561. First appearance of climatological zones.—562. Unsuccessful attempts to explain the uniform distribution of species in former ages.—563. The formation of downs—littoral deposits and the filling of lagoons and deltas supply chronological data of the present age.—564. Consistency of the Mosaic history with geological facts.—565. The future of the earth.—566. Accordance of the narrative in Genesis with geological facts.—567. Figurative use of the word day in accordance with common custom.—568. The division of the land from the water.—569. The creation of the vegetable world.—570. First creation of marine tribes and birds.—571. A similar order observed in geological phenomena.—572. Creation of Mammifers.—573. Correspondence with the Tertiary age.—574. Creation of the human race in the actual age.—575. Accordance of Scripture with geological discovery.—576. Conclusion.

531. THE order of Crustacea was that of the *Trilobites*, those of the Mollusca the Tentaculiferous Cephalopods, and the Brachio-pods; and that of the Radiata the fixed Crinoids. Two had their greatest number of genera in the Jurassic period. These were the *Saurian reptiles* and the *Free Crinoids*. Four had their greatest number in the Cretaceous period, of which two were Mollusca and two Radiata. In five, two had their greatest generic development in the Tertiary period, both being Mammalia, one *Pachydermata*, and the other *Edentata*. The *elephant* is a living example of the former, and the *sloth* of the latter.

From what has been stated, it appears that of the seventy-seven orders of animals, thirty-one were called into existence during the Palæozoic period. These were distributed among the four principal divisions of animal forms, as follows:—

Vertebrata	3
Annulata	11
Mollusca	9
Radiata	8

31

532. Thus the four principal divisions of animal forms were represented at the first moment of creation, in a relative numerical proportion not very different from that in which they still exist. This result is completely incompatible with a notion which has been long prevalent, that creative power manifested itself by

a gradually increasing degree of organic perfection from one geological period to another, from the first appearance of animal life upon the globe to the human period.

The only facts which have given colour to this supposition, are the lateness of the period at which the Vertebrated animals of the highest order of organisation, Mammifers and Birds, appeared in any considerable numbers upon the globe, and more especially the fact, that the human race did not appear until after the close of the Tertiary age.

533. That the conclusion thus deduced is a premature generalisation, will appear from an examination of the classes and genera which have prevailed, during all the successive ages from the Palæozoic to the human.

If the supposition of progressive improvement in organisation were well founded, it must naturally be expected that in the earliest period of the Palæozoic, the lowest orders only of organisation would appear, and that consequently the Radiata alone would be found there, while on ascending through the succeeding periods of the Triassic, Jurassic, Cretaceous, and Tertiary ages we should find gradually appearing the more perfect orders of Mollusca, Annulata, and Vertebrata. On the contrary, it appears, from what has been stated, that in the Palæozoic age animals of all the orders from the lowest to the highest were created in a proportion not very different from that in which they now exist.

534. It will be interesting, however, to consider the characteristics of the organisation of the genera composing each of the orders existing at each successive period; for although no progressive increase of perfection might be manifested with regard to the *orders*, such progression might nevertheless appear in the *genera* of these orders created from period to period.

535. A due examination, however, of the genera of the several orders existing at each period will show that no such progressive increase of perfection in the organisation has been manifested.

536. Of the Radiata eight orders were called into being in the Palæozoic age, and none of superior organisation in the succeeding ages. Indeed a rigorous examination of the succession of fauna of this division leads to the contrary conclusion, showing that the most perfect prevailed in greatest numbers at the earliest ages.

A similar examination of the division of Mollusca gives a like result, no gradually increasing perfection of organisation being discoverable.

537. In like manner the supposition of progressively improved organisation from age to age would lead us to expect in Annulated animals all the orders of the less perfect organisation in the

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first ages, and those of the more perfect in the later ones. As in the former cases, however, the actual results of observation are altogether opposed to this. Of the eleven orders of Annulata called into existence during the Palæozoic age there are three orders of insects—the Coleoptera, Orthoptera, and Neuroptera; one of the Arachnida, four of Crustacea, one of Cirrhipeds, and two of Annalids. Thus, as in the former case, all the classes are fairly represented. But we find further in these classes, among the three orders of Insects and four of Crustacea, the most perfectly organised of each class. We have therefore, in the case of the Annulata, the same results as were obtained in reference to the other two great divisions of the animal kingdom—the most perfectly organised being produced in the earliest ages; and not only was this the case, but they even there obtained their greatest development.

538. Although, as we have already stated, the Vertebrata present striking facts in favour of the supposition of progressive improvement already mentioned, a due examination of all the circumstances attending their gradual development, will show that no real progressive organisation has been manifested in them. If the supposition of progressively improving organisation were well founded, it must be expected that the Vertebrate animals of less complete organisation alone would appear in the Palæozoic age. We find on the contrary among the three orders of Vertebrata which appeared in that age, the Saurian reptiles and the Placoid and Ganoid fishes. Now, although mammifers and birds did not appear, the reptiles which did appear have a superior organisation to other orders which appeared later, such as serpents and Amphibia. The fishes of this epoch also are evidently superior in their organisation to many of the orders which appeared later. Although, therefore, only two of the four classes of the Vertebrata appeared during this age, of these two the most perfect specimens appeared the earliest, in contradiction to the supposition of progressively increasing perfection of organisation.

The Triassic age presented traces of the existence of the order of birds called *Waders*, and of *Chelonian reptiles* (tortoises). It is curious here to find at an epoch so remote in the history of the globe, birds the most perfect of the aerial Vertebrata, and the Chelonian reptiles, the most perfect of their class.

The Jurassic age presented no new orders of Vertebrata. The Cretaceous age presented one order of birds, the Web-footed; two of fishes, the Cycloids and Ctenoids, both less perfect than those of the Palæozoic age.

It was only, therefore, during the Tertiary age that the other

PROGRESSIVE ANIMALISATION.

orders of Vertebrata appeared. The orders of birds which appeared at this most recent epoch were not more perfect in their organisation than the waders of the Triassic age, while the orders of reptiles, including the serpents and Amphibia, were certainly the lowest in organisation of this class.

539. It appears, therefore, that of the four classes of Vertebrata, which appeared from the earliest geological age to the present time, two, the reptiles and fishes, instead of proceeding according to the supposition of progressively improving organisation, showed a series of changes of a directly opposite character, the most perfect being the earliest, and the least perfect the most recent; while the class of birds, with reference to their organisation only, and without reference to their number, remained stationary from the Triassic to the actual period.

540. A question of high philosophical interest arises in reference to the progressive animalisation of the globe, which admits of solution by a due examination of the organic remains deposited in the strata of the earth. This question is that of determining if the various organs of the most ancient animals have remained the same from the commencement of the world, or if they have been modified in consequence of the changes which may have taken place in the external conditions of their existence.

541. Of all the organs, those of respiration are most intimately connected with this question. The several modes of animal respiration are as follows:—

1. Cutaneous respiration, made by the whole surface of the body, and not by any special organ appropriated to that function.
2. Aquatic respiration, made by means of branchia, or gills; a special organ adapted to disengage the oxygen of the air from the water and appropriate it to the vital functions.
3. Tracheal respiration, with which animals are endowed which live in the atmosphere, and appropriate its oxygen to the vital functions by means of tracheæ.
4. Pulmonary respiration, which is performed by lungs, as in the case of Mammalia generally.

Marine animals respire either without any special organ and by means of the whole surface of their bodies, or by branchia (gills).

542. The animals which respire without any special organ, are those of the lowest degree of organisation. Of these all the four classes of Echinodermata, Polyparia, Foraminifera, and Amorphozoa, appeared on the earth in the Palæozoic age in various degrees of perfection. We have therefore here, in the first epoch of creation, all the forms of cutaneous respiration.

543. The animals which have aquatic respiration by means of

branchia (gills), include nearly all the Mollusca; among the Annulata they include the Crustacea, the Annalids, and the Cirrhipeds; and among the Vertebrata, all the fishes. We find all these represented in the Palæozoic age; and, on ascending from age to age, no modification of the respiratory apparatus is manifested. The living species which have branchial respiration belong to the same class as those which exercised like functions during the Palæozoic age.

544. All these circumstances lead, therefore, to the conclusion that the external conditions in which animals exist have undergone no essential change since the Palæozoic age, inasmuch as the organs of respiration have remained the same, a conclusion which is still further confirmed when, descending from the orders, the genera are examined.

545. In fine, to the question whether the marine animals have undergone any change in their structure since the first animalisation of the globe, or if they have greatly improved in their organisation, we may answer without hesitation by an absolute negative; for these primitive genera, or those most closely allied to them, which still represent them on the earth, prove that they had from the first the organic characters which they still preserve—that they have undergone no gradual improvement in organisation—that the medium in which they lived at the earliest epoch of the creation was the same as at present—that, therefore, no great change has taken place as to the conditions of vitality of these beings, and that the seas in which they then existed are essentially similar to those which they now inhabit.

546. All the terrestrial animals, whether of land or water, which breathe otherwise than by branchia, belong to the two classes which breathe either by trachea or lungs.

Less perfect than pulmonary, tracheal respiration is peculiar to the class of insects and some Arachnida. We find this function perfectly represented in the animals of the Palæozoic epoch. As has been already stated, Coleoptera, Orthoptera, and Neuroptera, all of tracheal respiration, have been discovered in the Palæozoic strata. As these insects belong to the same or analogous genera with those which now exist, we must assume that they were endowed with the same respiratory organs. We arrive, therefore, at the conclusion, as well for terrestrial animals which breathe by trachea, as for marine animals, that the respiratory organs have not undergone any progressive improvement, and that this class in the cradle of nature was what it still is; in fine, that the medium of its terrestrial existence has always been the same, since the first animalisation of the globe to the present time.

547. Pulmonary respiration prevails in three of the principal

GENERAL CONCLUSIONS.

divisions of the animal kingdom, the Vertebrata, Annulata, and the Mollusca.

The Annulata of early geological epochs, which had pulmonary respiration, belonged to the order of Arachnida. We find, in the Carboniferous strata, one of the Palæozoic group, the remains of an Arachnid (281, fig. 143), already mentioned, closely allied to the scorpion, which it is impossible to doubt had the same organisation as scorpions of the present day, and must, therefore, have lived under like conditions of animal existence.

548. Considered in relation to their geological date, Vertebrata breathing by true lungs are found during the Palæozoic age in the form of Saurians, the most perfect of reptiles. During the Triassic age tortoises and birds appear, which of all animals have the pulmonary system the most developed. It must, therefore, be inferred, that at these remote epochs, the medium in which birds and reptiles breathing the air by lungs lived, was little if at all different from the medium in which similar classes now live, which leads to the conclusion that, at this early period in the history of the globe, the composition of the atmosphere must have been nearly the same as at present.

549. All these considerations lead to the following general conclusions :—

First. If the supposition of a gradually increasing perfection of organisation were admitted, we ought to find all the animals endowed with mere cutaneous respiration in the first stages of the world, and the others, proceeding successively from age to age, endowed with branchial, tracheal, and pulmonary respiration, whereas, on the contrary, we find in the very first epoch of the animalisation of the globe, all the modes of respiration manifested at once—a conclusion entirely at variance with the supposition of progressively improving organisation.

Secondly. Whether we compare together the increasing or decreasing development of zoological forms, or the dates of the appearance of the orders of animals with the perfection of their organs; or take for the basis of our comparative researches the physiological conclusion deduced from the mode of respiration by animals, we uniformly arrive at the same negative results relatively to the supposition of progressive improvement of animal organisation. We must, therefore, accept it as proved, that no such progressive improvement has existed.

Thirdly. No appreciable modification being found in the organs of respiration of animals from the most ancient epoch to the present, a great number of genera having always existed with the same characters since the first animalisation of the globe, it must be inferred that the vital elements have not changed, and that

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the media in which animals existed, whether it be air or water, have remained the same both on land and sea.

Fourthly. The media of existence being always the same, no change in these media can be adduced as a cause for the successive extinctions and reproductions of the fauna of the earth, which have been manifested by geological phenomena as taking place during the successive geological periods, a conclusion of immense importance in the history of the globe.

Fifthly. All the researches which have been made in the fossil fauna, deposited in the strata of the earth, lead to a conclusion of high geological importance, that, until the epoch which immediately preceded the appearance of the human race and its contemporaneous tribes upon the globe, all that part of the earth which has undergone a close and accurate geological survey, including France, England, Germany, Italy, Switzerland, Spain, Portugal, part of Russia, and the adjacent seas, were inhabited by a fauna altogether tropical, and such as is at present found only under the torrid zone. We are forced, therefore, to the conclusion that, until the present period, the isothermal zones now observed had no existence.

550. Of 1473 fossil genera hitherto discovered, 16 only are found to exist in all the stages without exception. The remaining 1457 are distributed in different proportions throughout the stages. In some cases it is seen that certain genera are only found in a single stage; in others they prevail in two stages; in others in three or more; but, save in rare and exceptional cases, when they prevail in two or more stages, these stages are in regular geological succession. This persistence of the genera is a very important geological and palæontological fact. The exceptions to it do not exceed 3 per cent. of the entire number of fossil genera, and may, therefore, be regarded as arising from some accidental cause.

551. This peculiar distribution of generic forms of the fossils, supplies to the geologist most useful stratigraphical tests. Thus, if a genus known to exist only in one peculiar geological stage, be found in any part of the crust of the earth whose structure has not been previously well ascertained, its presence may be taken as a certain indication of the character and position of the stage in which it is deposited.

The Contemporaneous Age.

HUMAN PERIOD.

552. The disruption of the earth's crust, extending W. 16° S., and E. 16° N., through which the chain of the great Alps was

HUMAN PERIOD.

forced up to its present elevation (220), which, according to M. D'Orbigny, was simultaneous with that which forced up the Chilian Andes, a chain which extends over a length of 3000 miles of the Western Continent, terminated the Tertiary age, and preceded immediately the creation of the human race and its concomitant tribes. The waters of the seas and oceans, lifted from their beds by this immense perturbation, swept over the continents with irresistible force, destroying instantaneously the entire fauna and flora of the last Tertiary period, and burying its ruins in the sedimentary deposits which ensued.

553. By this dislocation, Europe underwent a complete change of form. Among the most remarkable effects were the separation of the British Isles from the mainland by the subsidence of the land between Brittany and Normandy on the one side, and Cornwall and Devon on the other, and the consequent irruption of the sea. The Mediterranean, separated from the ocean, enlarged its limits by submerging a tract south of Marseille, which had remained dry since the commencement of the Tertiary age. Europe in general took its present form and relief, with the exception of some alluvial tracts, which at a more recent period were raised above the waters, either by the disruption which produced the system of Tænarus (221) and raised Etna, Vesuvius, and Santorini, or by other local disturbances of less importance, such as partial earthquakes.

554. Secondary effects followed, which have left their traces on every part of the earth's surface. Rivers of immense magnitude poured their streams from all the elevated summits over the subjacent plains, spreading out from point to point of their course into extensive lakes, on the bottoms of which they deposited those alluvial strata of which so many examples are presented in the valleys, plains, and provinces of all the great continents. In Europe such deposits are seen in the valleys of the Rhine, the Rhone, and other great rivers, on the great plain of Crau, in the south of France, having an extent of fifty square leagues, on the plain of Bavaria, and that which spreads itself out at the foot of the Alps over the state of Lombardy and Venice.

555. When the seas had settled into their new beds, and the outlines of the land were permanently defined, the latest and greatest act of creation was accomplished by clothing the earth with the vegetation which now covers it, peopling the land and water with the animal tribes which now exist, and calling into being the human race, appointed to preside over all living things, and to manifest the glory of the Creator by the development of attributes so exalted, as to be described by the inspired author of Genesis as rendering man in a certain sense the image of his Maker.

THE PRE-ADAMITE EARTH.

556. To convey an approximate estimate of this fauna, we have collected and arranged, from the data supplied by M. D'Orbigny, in the following table a synopsis of the total number of generic forms of each class.

Synopsis of the generic forms included in all the fauna (exclusive of the Annulata), from the first animalisation of the earth to the human period inclusively.

	Total number, living and fossil.	LIVING.			FOSSIL.		
		Created.	Revived.	Total.	Extinct.	Living.	Total.
Mammifers	279	164	47	211	68	47	115
Birds	300	256	38	294	6	38	44
Reptiles	200	133	13	146	54	13	67
Fishes	638	360	79	439	199	79	278
Crustacea	268	168	32	200	68	32	100
Cephalopods, acetabuliferous	33	15	5	20	13	5	18
„ tentaculiferous	36	..	1	1	35	1	36
Gastropods, terrestrial and fluviatile	22	5	16	21	1	16	17
„ marine	146	25	90	115	31	90	121
Lamellibranchia, fluviatile	11	6	5	11	..	5	6
„ marine	101	9	67	76	25	67	92
Brachiopods	41	..	9	9	32	9	41
Bryozoa	87	18	21	39	48	21	69
Echinodermata, echinoids	92	21	22	43	49	22	71
„ crinoids	59	1	2	3	56	2	58
„ asteroids	20	14	3	17	3	3	6
„ ophiuroids	20	10	1	11	9	1	10
Zoophytes	309	93	38	131	178	38	216
Foraminifera	87	14	50	64	23	50	73
Amorphozoa, testaceous	36	1	..	1	35	..	35
„ corneous	15	14	1	15	..	1	1
	2800	1327	540	1867	933	540	1473

557. It appears from this, that so far as observation has supplied data for such an estimate, the total number of generic animal forms which have been called into being, since the first animalisation of the earth to the present time, has been 2800. Of this number, 1327, or nearly the half, were created at the commencement of the human period, a large proportion for one period out of thirty. It must be observed, however, that it is extremely improbable that the number of genera in past periods is as well ascertained as in the present. In the one case we have the living creation to count from; in the other we have nothing but the buried remains of the fauna of each period.

Of the number of genera, 1473, that lived in previous ages, only 540 have reappeared. There are therefore 933 generic forms unknown to the present fauna. These, as we have seen, however,

NUMBER OF GENERIC FORMS CREATED.

were not simultaneously extinguished, a certain number disappearing for ever at the close of each period.

558. The specific forms are far more numerous, and not so exactly ascertained. Those of fossil Mollusca and Radiata have been elaborately described and catalogued by M. D'Orbigny, who, as we have already stated, has shown that each successive period had its own assemblage of species. In the following table, compiled from the *Prodrome de Paléontologie* of that eminent naturalist, we have given a synopsis of the distribution of species in the successive ages and periods.

Table showing the number of species of Mollusca and Radiata by the fossil remains that have lived during the successive geological epochs and periods.

		Number of Species.	
TERTIARY AGE.	Fifth period	606	6042
	Third and fourth period	3182	
	Second period	1576	
	First "	678	
CRETACEOUS AGE.	Seventh period	66	4291
	Sixth "	1579	
	Fifth "	380	
	Fourth "	849	
	Third "	410	
	Second "	156	
	First "	851	
JURASSIC AGE.	Tenth period	60	3846
	Ninth "	199	
	Eighth "	655	
	Seventh "	739	
	Sixth "	281	
	Fifth "	546	
	Fourth "	603	
	Third "	288	
	Second "	301	
	First "	174	
TRIASSIC AGE.	Second period	792	927
	First "	135	
PALÆOZOIC AGE.	Fifth period	91	3180
	Fourth "	1047	
	Third "	1198	
	Second "	418	
	First "	426	
Total		18286	18286

559. Since the date of the publication of this table, the number of ascertained species of fossil Mollusca and Radiata has been increased by further discovery, and now amounts to 21000, to which 3000 fossil species of Vertebrata and Annulata being added, gives a total number of fossil specific forms, amounting to 24000.

560. The most conspicuous condition which distinguishes the

THE PRE-ADAMITE EARTH.

present from all past periods, is the existence of the human race among its fauna, the attributes of which are so peculiar as to place it out of all analogy with the other classes of animals.

561. Another striking physical difference between the present and all former periods, consists in the different divisions of the earth's surface into climatological zones, each zone having its peculiar fauna and flora. In all former ages and periods, including those which immediately preceded the present, no traces of climatic distinctions have been found. It has been already shown that the fossil fauna and flora of latitudes the most different, are analogous to the fauna and flora of warm climates. Now since this uniform temperature can only be ascribed to the great predominance of the effects of the central heat of the earth over those of solar radiation, it might naturally be supposed that the change would have been gradual, and that as the surface of the earth would have cooled down by degrees, climates would have been gradually manifested, the first differing but slightly in temperature, and then from period to period the difference increasing, until at length the earth would arrive at its present condition, exhibiting the extremes and means of the torrid temperate, and frigid zones.

Observation nevertheless has not as yet supplied any facts to confirm such theoretical views. On the contrary, in the fifth Tertiary period, which immediately preceded the present epoch, it is certain that the higher latitudes had a climate similar to that which now prevails towards the Line. Plants, now limited to southern latitudes, flourished in Europe. The palms, for example, which vegetated there, have completely disappeared, having retired to warmer regions. The elephant, rhinoceros, panther, and other tropical animals which abounded in high latitudes, have also wholly disappeared there, and are limited to those latitudes where a temperature prevails conformable to their organisation. The bear still lives in Europe, but not the species which is found entombed in the strata.

562. To render the fossil fauna compatible with the existence of isothermal lines, it has been supposed that the remains of animals and plants, peculiar to warm climates, which are deposited in the strata of high latitudes, may have been transported there by ocean currents. That such an hypothesis is inadequate and inadmissible, is demonstrated by the universality of the tropical fauna of all periods. The remains, especially of land animals and vegetables, which could by any possibility have been transported by such means, must necessarily have been few and local, and would appear merely as exceptions and anomalies among the fauna and flora proper to the climatic loca-

lity. No such condition of fossil deposits, however, is observed, those of the highest latitudes being as decidedly tropical as those of the lowest.

563. The formation of downs, littoral deposits, the filling up of lagoons, and the conversion of deltas into tracts of land, are severally contemporaneous geological phenomena, which serve, by the rate of their progress, and by their cumulative effects, as a sort of natural chronometers, by which the age of the human race, and its contemporary fauna, may be approximately estimated; and it is as remarkable as it is satisfactory, that the results are in no degree of discordance with the dates of Creation supplied by chronology, based on tradition and revelation. By the general accordance of such facts, it appears that the present period has now continued for not more than six or seven thousand years.

564. After all that has been explained of the series of convulsions which terminated the succession of periods in the history of the earth, it will be evident that the Mosaic narrative of the Deluge contains nothing incompatible with that course of events, which may be said, without exaggeration, to have been of habitual occurrence on our planet. Whether the Deluge be identified with the catastrophe which produced the system of Tænarus or be ascribed to other convulsions, such as extensive earthquakes, is immaterial, so far as respects the mere credibility of the narrative. It is worthy of remark also, that the Mosaic narrative is in accordance with national tradition among various peoples.

565. As to the future, all inference must be based upon analogy with the past. During a succession of eight or nine and twenty periods, we have seen that creation after creation has taken place. Assemblage after assemblage of animated beings have peopled the earth, which has been clothed and re-clothed with vegetation for their well-being. Upon the close of period after period, it has pleased the Most High, in his inscrutable wisdom, to doom such animated worlds to sudden destruction, attaining His purpose by the secondary agency of geological convulsions. The existing animated world presents nothing which can take it out of the category of the past, or exempt it from the ultimate fate which an inexorable law has prescribed to all former creations. The earth is still subject to the same local oscillations of its crust, whether continual and gradual, or violent and sudden, as heretofore. Volcanic phenomena declare, in unequivocal language, that the heavings of the internal fluid and incandescent matter have lost none of their terrific energy. Not only, therefore, does nothing justify the supposition that the convulsion which raised the chain of the great Alps, and destroyed the fauna and flora of the fifth

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Tertiary period, was the last to which the earth would be subjected, but every probability, based upon analogy to the past, points to the very opposite conclusion. When we affirm, therefore, that a moment must arrive when what we call the present world will be destroyed, when man, and all his monuments, will be involved in one common destruction, when

“The cloud-capt towers, the gorgeous palaces,
The solemn temples, the great globe itself,
Yea, all that it inherits shall dissolve;
And, like an unsubstantial pageant faded,
Leave not a rack behind,”

we declare no more than all the analogies of the past history of the Earth confirm.

But such finality will not, as Shakspeare implies, involve the “great globe itself.” The law of periodicity which characterises in a manner so remarkable all the other phenomena of nature, reappears in the acts of creation itself, and pronounces in terms not to be misunderstood the future fate of the present tenants of the earth, and shadows forth its future destination. The convulsion which will sweep away man and his works, and the tribes of animals and vegetables created for his use, and will entomb their remains, will be followed by a calm of nature, after which, if we are to trust in the permanency of the play of those creative laws which have hitherto characterised the operations of Divine power, a new assemblage of organised beings will be called into life, and a new flora will clothe the earth. Inteligences will preside over this new world with faculties as much exalted above those with which man in all his pride is endowed, as the understanding of man himself is above that of the apes, monkeys, and baboons which were at the head of the population of the last period of the Tertiary age.

566. The short account of the Creation given in the first chapter of Genesis is in accordance with the results of geological discovery, in as complete a manner as would be possible in so brief a summary, destined, not to instruct the world in geology, but, without violating truth, to convey a general notion of the work of Omnipotence in the process of creation. Light was first created, that is, the universally diffused ether, by whose properties not only light, but heat and probably electricity and magnetism, if not gravity itself, severally exist. The firmament was next made, that is, space and the stars in countless numbers which occupy it, each of which is a centre of attraction to a group of surrounding bodies, and among these stars the sun.

567. According to Genesis, the organic creation was produced in four successive intervals of time, figuratively called Days, as

ORDER OF CREATION.

we now apply that term to any period during which a certain succession of phenomena are manifested. Thus we speak of the morning and the evening of life.

“’Tis the sunset of life gives me mystical lore,
For coming events cast their shadows before.”

568. The first epoch was preceded by the formation of the outlines of land and water. The rupture of the incipient crust of the earth, as already explained (100), by throwing the solid surface into different levels, divided the earth into oceans, seas, continents, and islands. This is stated briefly but distinctly enough in Gen. i. 9, 10: “And God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear, and it was so. And God called the dry land Earth, and the gathering of the waters called he Seas: and God saw that it was good.”

569. The surface of the land was now clothed with vegetation. Verses 11, 12: “And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so. And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good.”

570. The second epoch of organic creation was signalled by the production of animal life in its lowest forms, being limited to marine tribes included under the general and familiar name of Fishes. Verse 20: “And God said, Let the waters bring forth abundantly after their kind.” This was succeeded by the creation of Birds: “And every winged fowl after his kind: and God saw that it was good. And God blessed them, saying, Be fruitful, and multiply, and fill the waters in the seas, and let fowl multiply in the earth.”

571. In complete accordance with this account geological researches show, that in the stages which immediately rest upon the azoic formation beds of coal are found, proving that the first land was clothed with vegetation. The animal remains found in the same deposits, consist almost exclusively of marine tribes. Some foot-tracks of birds, as we have shown, are also found in these formations. No traces of land animals yet appear. Thus in accordance with Genesis, geology announces that the first acts of creation were the production of “the grass, the herb yielding seed, and the tree yielding fruit after its kind,” and that then the Creator caused the “waters to bring forth abundantly after their kind,” and called into existence every winged fowl after its kind.

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572. The third epoch of creation was signalled by the production of Mammifers and of land animals generally (ver. 24): "And God said, Let the earth bring forth the living creature after his kind, cattle, and creeping thing, and beast of the earth after his kind: and it was so. And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind: and God saw that it was good."

573. The later geological ages, and especially the Tertiary, are here indicated, in which, as has been shown, the tribes mentioned in this short and popular statement were created.

574. The fourth, last, and latest great act of Omnipotence was the creation of the human race. On the last day or epoch of creation, "God said, Let us make man in our own image, after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle of the field, and over all the earth, and over every creeping thing that creepeth upon the earth. So God created man in his own image, in the image of God created he him; male and female created he them."

575. It is perhaps in this last part of the Mosaic narrative that the most striking and interesting accordance with geological science is observable. According to Genesis, the last epoch of creation was exclusively given to the creation of the human race. Naturalists have reduced animal forms to seventy-eight orders, in one of which man stands alone. It appears from the researches of palæontologists that of these seventy-eight, all but one,—that including man,—were created before the close of the Tertiary period, and that in the creation which followed that period, man was the only animal order added to those of former creations.

576. I have thought it right to develop these points at some length, inasmuch as many consciences have felt alarm at the supposed discordance between Scriptural history and geological discovery. It will, however, be seen, from what I have here stated, that not only no such discordance exists, but that making such allowances for the latitude of language, as are indispensable in the interpretation of so brief and popular a description, designed not for the scientific but for the mass of mankind, as that given in Genesis, there is the most remarkable and satisfactory accordance with natural phenomena.

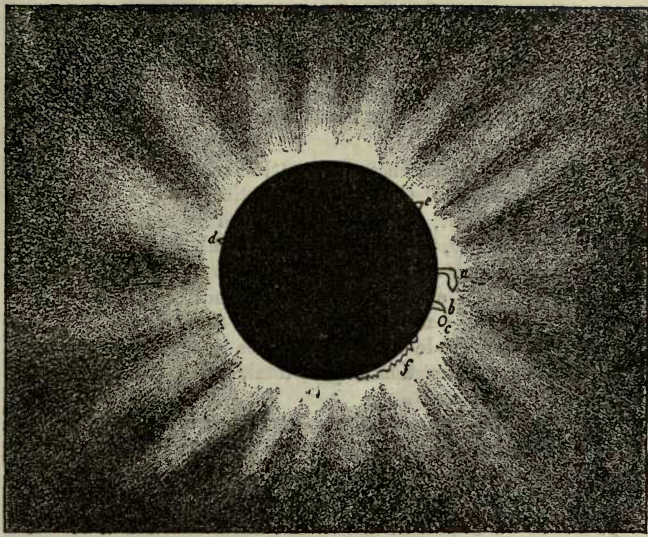


Fig. 13.

ECLIPSES.

CHAPTER I.

1. Mutual interposition of celestial objects.—2. Their mutual obscuration.—3. Eclipses, transits, and occultations.—4. Solar eclipse.—5. Lunar eclipse.—6. Transit of a planet.—7. Occultation of a fixed star.—8. Appearance produced by transit of an inferior planet. **SOLAR ECLIPSES:** 9. Effects of the relative magnitude of the discs of the sun and moon.—10. Conditions which determine eclipses.—11. Conditions under which an eclipse does not take place.—12. Condition of external contact.—13. Condition of partial eclipse—determination of its magnitude.—14. Internal contact.—15. Annular eclipse.—16. Total eclipse.—17. Greatest possible duration of a total eclipse.—18. Condition of annular eclipses.—19. Greatest possible duration of annular eclipses.—20. Solar eclipses can only occur at or near a new moon.—21. Effects of parallax.—22. Data which determine the circumstances of eclipses.—23. Solar ecliptic limits.—24. Anecdote of Columbus.—25. Baily's beads.—26. These appearances produced by lunar mountains.—27. Flame-like protuberances round the dark disc of the moon.—

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28. Solar eclipse of 1851.—29. Observations of the Astronomer Royal upon it.—30. Observations of Messrs. Dunkin and Humphreys upon it.—31. Observations of Mr. W. Gray upon it.—32. Observations of Messrs. Stephenson and Andrews at Fredrichsvaarn.—33. Observations of Mr. Lassell at Trollhättan Falls.—34. Observations of Mr. Hind at Ravelsborg, near Engelholm.

1. OF the objects which in such countless numbers are scattered over the firmament, all those which constitute the solar system, except the sun itself, are in motion; and it must necessarily happen, occasionally, that some of them will assume a position between others and the eye of the observer placed upon the earth. When such an event happens the nearer of the two will intercept wholly or partially the view of the more distant. If the apparent magnitude of the nearer be greater than the more distant, such an obstruction may be total, but if less it can only be partial.

2. Since all the bodies of the solar system are illuminated by the sun, and when deprived of the sun's light are obscured and cease to be visible, it may also happen that some one of the bodies composing the system may intervene between the sun and another body, so as to deprive the latter of the light which it receives from that luminary. In such a case the object deprived of light will be rendered wholly or partially invisible, according to the relative magnitude of the two bodies, the one intercepting the light and the other being obscured.

3. Such conjunctions produce a class of occasional astronomical phenomena, which are invested with a high popular as well as a profound scientific interest. The rareness with which some of them are presented, their sudden and, to the vulgar mass, unexpected appearance, and the singular phenomena which often attend them, strike the popular mind with awe and terror. To the astronomer, geographer, and navigator, they subserve important uses, among which the determination of terrestrial longitudes, the more exact estimation of the sun's distance from the earth (which is the standard and modulus of all distances in the celestial spaces), and, in fine, the discovery of the mobility of light, and the measure of its velocity, hold foremost places.

The phenomena resulting from such contingencies of position and direction are variously denominated ECLIPSES, TRANSITS, and OCCULTATIONS, according to the relative apparent magnitudes of the interposing and obscured bodies, and according to the circumstances which attend them.

4. When the disc of the moon passes between an observer and the disc of the sun, it intercepts in this manner more or less

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of the latter, and produces the phenomenon called a *solar eclipse*.

5. When the globe of the earth intervenes between the moon and the sun, it intercepts the light of the latter from a greater or lesser part of the moon's disc, and produces the phenomenon called a *lunar eclipse*.

6. When a satellite of a planet passes into such a position that the globe of the planet intervenes between the satellite and the sun, the latter is eclipsed.

7. When the disc of the moon or of a planet passes between the eye of an observer and a fixed star, the star suddenly disappears, and the phenomenon is called an *occultation* of the star.

8. When a planet passes between an observer and the sun's disc there is seen projected upon the latter a small black circular spot, and in virtue of the relative motion of the sun and planet this black spot appears to pass across the disc of the sun from east to west, producing the phenomenon called a transit of the planet. Since at the period of a transit the planet must be between the sun and the earth, and therefore nearer to the sun than the earth, this phenomenon can only happen with an inferior planet. The only planets, therefore, of which there can be transits are Venus and Mercury.

SOLAR ECLIPSES.

9. The discs of the sun and moon, though nearly equal, are not exactly so, each being subject to a variation of magnitude confined within certain narrow limits; and, in consequence, the disc of the moon is sometimes a little greater, and sometimes a little less, than that of the sun. Their centres move in two apparent circles on the firmament; that of the sun in the ecliptic, and that of the moon in a circle inclined to the ecliptic at a small angle of about 5° . These circles intersect at two opposite points of the firmament, called the moon's nodes. In consequence of the very small obliquity of the moon's orbit to the ecliptic, the distance between these paths, even at a considerable distance at either side of the node, is necessarily small. Now, since the centres of the discs of the sun and moon must each of them pass once in each revolution through each node, it will necessarily happen from time to time that they will be both at the same moment either at the node itself, or at some points of their respective paths so near it, that their apparent distance asunder will be less than the sum of their apparent semi-

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diameters, and either total or partial interposition must take place, according to the relative magnitudes of their discs, and to the distance between the points of their respective paths at which their centres are simultaneously found.

10. This will be easily rendered intelligible. Let A , fig. 1, be the disc of the object eclipsed, and a be that of the interposing object which eclipses it. So long as the distance between the centres of the two discs is greater than the sum of their semi-diameters, it is evident that the one disc will lie altogether outside the other, so as not to intercept the view of any part of it. This will be apparent from an inspection of fig. 1.

11. This may be briefly explained thus: If R be the semi-diameter of A , and r that of a , and D be the distance between the two centres, then the one disc will lie altogether outside the other so long as D is greater than $R + r$.

Fig. 1.

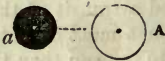


Fig. 2.



12. If the distance between the centres be equal to the sum of the two semi-diameters, then the two discs will touch each other, without either actually intercepting a part of the other. This case is shown in fig. 2, and is briefly explained thus: If $D = R + r$, the two discs will touch without encroaching one upon the other. This position of the discs is called *external contact*.

13. If the distance between the centres of the two discs be less than the sum of the two semi-diameters, then one of the discs will necessarily encroach upon the other and a partial eclipse will take place. This case is shown in fig. 3. The breadth of the

Fig. 3.



Fig. 4.



part of the disc A obscured by a is evidently equal to the difference between the sum of the semi-diameters of the two discs and the distance between their centres, which is briefly expressed thus: If $R + r$ be greater than D , then the one disc will encroach upon the other, and the breadth of the part intercepted will be

$$R + r - D.$$

14. If the distance between the centres of the two discs be

SOLAR ECLIPSES.

equal to the difference of the semi-diameters, then the one disc will lie within the other, just touching it, as shown in fig. 4. This position of the disc is called that of *internal contact*, which therefore takes place when

$$D = R - r.$$

15. If the distance between the centres be less than the sum of the semi-diameters, but greater than their difference, then a partial interposition will take place, as shown in fig. 3. If the interposing disc be less than the obscured disc, and the distance between their centres be less than the difference between the semi-diameters, then the interposing disc will lie within the obscured disc, leaving a round ring of illuminated surface, not intercepted, as shown in fig. 5. If, in this case, the centres of

Fig. 5.



Fig. 6.



the two discs coincide, the surrounding ring of light will be of uniform breadth.

Such phenomena are called *annular eclipses*, and when the centres coincide they are said to be *central and annular*.

16. If the interposing disc be greater than the intercepted one, and at the same time the distance between the centres less than the difference of the semi-diameters, then the interposing disc will cover completely the other, and a total eclipse will take place, as shown in fig. 6. If in this case the centres of the two discs coincide, the eclipse is said to be *total and central*. In the case of the sun and moon the magnitude of eclipses are expressed by what are called *digits*. If the diameter of the eclipsed object, be it sun or moon, be supposed to be divided into twelve parts, each of which is called a *digit*, the eclipse is said to measure as many digits as there are such parts in the greatest breadth of the obscured part, that is, in the difference between the sum of the semi-diameter of the sun and moon and the distance between their centres. To produce a total solar eclipse, it is therefore necessary, 1st, that the apparent diameter of the moon should be equal to or greater than that of the sun; and, 2ndly, that the apparent places of their centres should approach each other within a distance not greater than the difference of their apparent semi-diameters. When these conditions are fulfilled, and so long as they continue to be fulfilled, the eclipse will be total.

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17. The greatest value of the apparent semi-diameter of the moon being $1006''$, and the least value of that of the sun being $945''$, we shall have for the difference of their semi-diameters $61''$. The greatest possible duration, therefore, of a total solar eclipse will be the time necessary for the centre of the moon to gain upon that of the sun $61'' \times 2 = 122''$. But since the mean synodic motion of the moon is at the rate of $30''$ per minute, it follows that the duration of a total solar eclipse can never exceed four minutes.

18. When the apparent diameter of the moon is less than that of the sun, its disc will not cover that of the sun, even when concentrical with it. In this case, a ring of light would be apparent round the dark disc of the moon, the breadth of which would be equal to the difference of the apparent semi-diameters, as represented in fig. 5. When the discs are not absolutely concentrical, the distance between their centres being, however, less than the difference of their apparent semi-diameters, the dark disc of the moon will still be within that of the sun, and will appear surrounded by a luminous annulus, but in this case the ring will vary in breadth, the thinnest part being at the point nearest to the moon's centre; and when the distance between the centres is reduced to exact equality with the difference of the apparent semi-diameters, the ring becomes a very thin crescent, the points of the horns of which unite, as represented in fig. 4.

The greatest breadth of the crescent will be in this case equal to the difference of the apparent diameters of the sun and moon.

The greatest apparent semi-diameter of the sun being $16' 18''$, and the least apparent semi-diameter of the moon being $14' 44''$, the greatest possible breadth of the annulus when the eclipse is central will be

$$16' 18'' - 14' 44'' = 1' 34'' = 94'',$$

which is about the 20th part of the mean apparent diameter of the sun.

19. The greatest interval during which the eclipse can continue annular is the time necessary for the centre of the moon to move synodically over $94'' \times 2 = 188''$, and, since the mean synodic motion is at the rate of $30''$ per minute, this interval will be about

$$\frac{188}{30} = 6.26 \text{ minutes, or about six minutes and a quarter.}$$

20. Solar eclipses can only occur at or near a new moon. This

SOLAR ECLIPSES.

is evident, because the condition which limits the apparent distance between the centres of the discs to the sum of the apparent semi-diameters, involves the consequence that this distance cannot much exceed $30'$, and as the difference of longitudes must be still less than this, it follows that the eclipse can only take place within less than half a degree in apparent distance, and within less than two hours of the epoch of conjunction.

21. Since the visual directions of the centres of the discs of the sun and moon vary more or less with the position of the observer upon the earth's surface, the conditions which determine the occurrence of an eclipse, and if it occur, those which determine its character and magnitude, are necessarily different in different parts of the earth. While in some places none of the conditions are fulfilled, and no eclipse occurs, in others an eclipse is witnessed which varies from one place to another in its magnitude, and in some may be total while it is partial in others.

If the change of position of the observer upon the earth's surface affected the visual directions of the centres of the two discs equally, which would be the case if they were equally distant, or nearly so, no change in the apparent distance between them would be produced, and in that case the eclipse would have the same appearance exactly to all observers in every part of the earth. But the sun being about 400 times more distant than the moon, the visual direction of the centre of its disc is affected by any difference of position of the observers, to an extent 400 times less than that of the moon's centre.

22. The relative positions of the discs of the sun and moon in the firmament, their apparent motions, and the effect produced upon their apparent positions by the varying positions of the observer upon the earth, being all known, the circumstances which determine the magnitude from minute to minute of the distance between their centres, are all given; and the problem to determine the beginning of the eclipse, or the moment at which the distance between the centres becomes equal to the sum of their apparent diameters; and the end of the eclipse, or the moment when, after diminishing and then increasing, it again becomes equal to the sum of their apparent diameters, is a matter of easy arithmetical calculation, although the practical details of such processes would not be suitable to the readers of this Tract.

23. The moon's orbit being inclined to the ecliptic at an angle of 5° , and, consequently, the distance of the moon's centre from the ecliptic varying in each month from 0° to 5° , while the interposition of the moon between any place on the earth and the sun, requires that the apparent distance of their centres should

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not exceed the sum of their apparent semi-diameters, which never much exceeds half a degree, it is clear that an eclipse can never happen except when, at the time of conjunction, the apparent distance of the moon's centre from the ecliptic is within that limit, a condition which can only be fulfilled within certain small distances of the moon's nodes.

There is a certain distance from the moon's node, beyond which a solar eclipse is impossible, and a certain lesser distance, within which that phenomenon is inevitable. These distances are called the solar ecliptic limits.

24. Columbus is said to have availed himself of his acquaintance with practical astronomy to predict a solar eclipse, and used the prediction as a means of establishing his authority over the crews of his vessels, who showed indications of mutinous disobedience.

The spectacle presented during a total eclipse is always most imposing. The darkness is sometimes so intense as to render the brighter stars and planets visible. A sudden fall of temperature is sensible in the air. Vegetables and animals comport themselves as they are wont to do after sunset. Flowers close, and birds go to roost. Nevertheless, the darkness is different from the natural nocturnal darkness, and is attended with a certain indescribable unearthly light, which throws upon surrounding objects a faint hue, sometimes reddish, and sometimes cadaverously green.

Many interesting narratives have been published by scientific observers who have been so fortunate as to witness these phenomena.

25. When the disc of the moon, advancing over that of the sun, has reduced the latter to a thin crescent, it was observed by Mr. Francis Baily, that immediately before the beginning, or after the end of complete obscuration, the crescent appeared as a band of brilliant points separated by dark spaces, so as to give to it the appearance of a string of brilliant "beads." The phenomenon, which has since been frequently re-observed, thence acquired the name of "Baily's beads."

Further observation showed, that, before the formation of the "beads," the horns of the crescent were sometimes interrupted and broken by black streaks thrown across them.

These phenomena are roughly sketched in figs. 7, 8.

Figs. 9, 10, 11, 12, are taken from the original sketches of Mr. Baily, representing the progressive disappearance of the beads after the termination of the complete obscuration.

26. These phenomena arise from the projections of the edge of the moon's disc, serrated by numerous inequalities of the surface,

BAILY'S BEADS.

approaching so close to the external edge of the sun's disc, that the points of the projections extend to the latter, while the

Fig. 7.

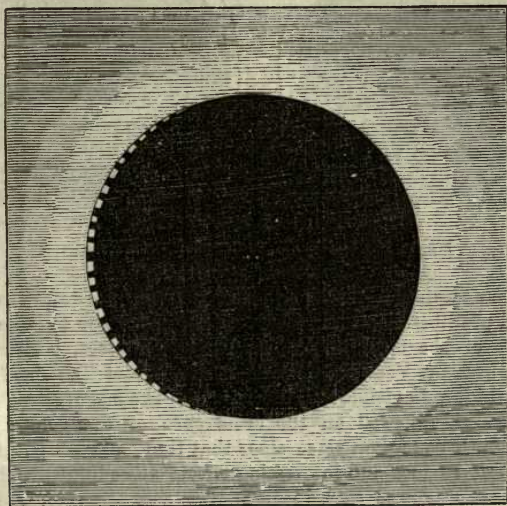
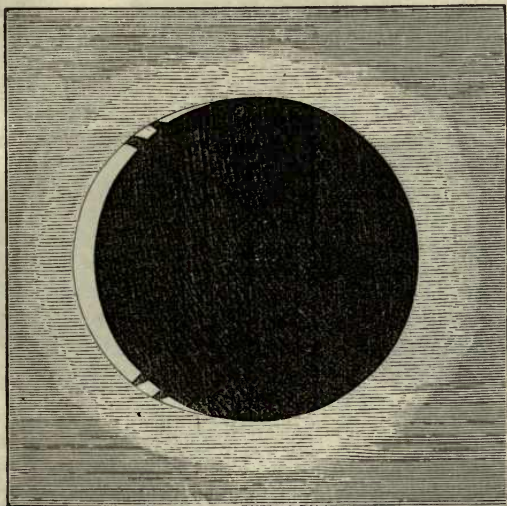


Fig. 8.

ECLIPSES.

intermediate spaces remain uncovered. This may be very appropriately illustrated by laying the blade of a circular saw, having finely cut teeth, over a white circle of nearly equal diameter upon a black ground. The white parts between the teeth will appear like a necklace of white pearls.

Fig. 9.

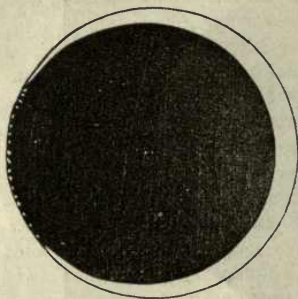


Fig. 10.

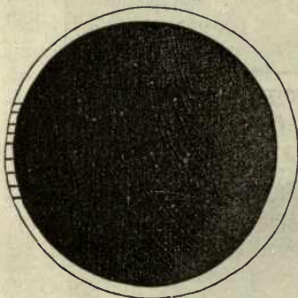
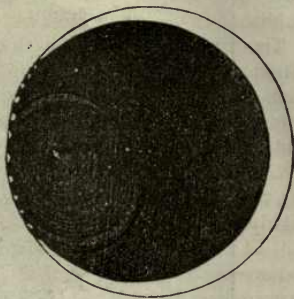


Fig. 11.

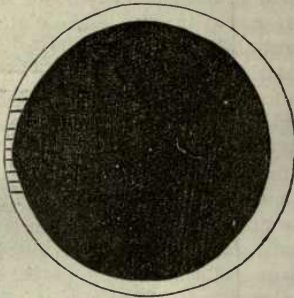


Fig. 12.

27. Immediately after the commencement of the total obscuration, red protuberances, resembling flames, appear to issue from the edge of the moon's disc. These appearances, which were first noticed by Vassenius, on the occasion of the total solar eclipse which was visible at Göttenberg on the 3rd of May, 1733, have been re-observed on the occurrence of every total solar eclipse which has taken place since that time, and constitute one of the most curious and interesting effects attending this class of phenomena.

28. A total eclipse of the sun took place on the 28th of July,

1851, which became a subject of systematic observation by the most eminent astronomers of the present day. A considerable number of English observers, aided by several foreigners, distributed themselves in parties at different points along the path of the shadow, so that the chances of the impediments that might arise from unfavourable conditions of the atmosphere might be diminished. The reports and drawings of these various observers have been collected by the Royal Astronomical Society, and published in their transactions.

The Astronomer Royal, with two assistants, Messrs. Dunkin and Humphreys, authorised by the Board of Admiralty, selected certain parts of Sweden and Denmark as the most eligible stations. Professor Airy observed at Göttenberg, Mr. Dunkin at Christiana, and Mr. Humphreys, assisted by Mr. Miland, at Christianstad.

29. The weather on the whole proved favourable at Göttenberg. We take from the report of the Astronomer Royal the following highly interesting particulars of the progress of the phenomenon.

“The approach of the totality, was accompanied with that indescribably mysterious and gloomy appearance of the whole surrounding prospect, which I have seen on a former occasion. A patch of clear blue sky in the zenith became purple-black while I was gazing at it. I took off the higher power, with which I had scrutinised the sun, and put on the lowest power (magnifying about 34 times). With this I saw the mountains of the moon perfectly well. I watched carefully the approach of the moon’s limb to the sun’s limb, which my graduated dark glass enabled me to see in great perfection; I saw both limbs perfectly well defined to the last, and saw the line becoming narrower and the cusps becoming sharper without any distortion or prolongation of the limbs. I saw the moon’s serrated limb advance up to the sun’s, and the light of the sun glimmering through the hollows between the mountain peaks, and saw these glimmering spots extinguished one after another in extremely rapid succession, but without any of the appearances which Mr. Baily has described. I saw the sun covered, and immediately slipping off the dark glass, *instantly* saw the appearances represented at *a b c d*, fig. 13 (p. 161).

“Before alluding more minutely to these, I must advert to the darkness. I have no means of ascertaining whether the darkness really was greater in the eclipse of 1842; I am inclined to think that in the wonderful, and I may say appalling, obscurity, I saw the grey granite hills within sight of Hvaläs more distinctly than the darker country surrounding the Superga. But whether because in 1851 the sky was much less clouded than in 1842 (so that the transition was from a more luminous state of sky to a

darkness nearly equal in both cases), or from whatever cause, the suddenness of the darkness in 1851 appeared to me much more striking than in 1842. My friends who were on the upper rock, to which the path was very good, had great difficulty in descending. A candle had been lighted in a lantern about a quarter of an hour before the totality; Mr. Haselgren was unable to read the minutes of the chronometer-face without having the lantern held close to the chronometer.

"The corona was far broader than that which I saw in 1842: roughly speaking, its breadth was little less than the moon's diameter; but its outline was very irregular. I did not remark any beams projecting from it which deserved notice as much more conspicuous than the others; but the whole was beamy, radiated in structure, and terminated (though very indefinitely) in a way which reminded me of the ornament frequently placed round a mariner's compass. Its colour was white, or resembling that of *Venus*. I saw no flickering or unsteadiness of light. It was not separated from the moon by any dark ring, nor had it any annular structure; it looked like a radiating luminous cloud behind the moon.

"The form of the prominences was most remarkable. That which I have marked *a* reminded me of a boomerang. Its colour for at least two-thirds of its breadth, from the convexity towards the concavity, was full lake-red, the remainder was nearly white. The most brilliant part of it was the swell farthest from the moon's limb; this was distinctly seen by my friends and myself with the naked eye. I did not measure its height; but judging generally by its proportion to the moon's diameter, it must have been 3'. This estimation perhaps belongs to a later period of the eclipse. The prominence *b* was a pale white semi-circle based on the moon's limb. That marked *c* was a red detached cloud, or balloon, of nearly circular form, separated from the moon's limb by a space (differing in no way from the rest of the corona) of nearly its own breadth. That marked *d* was a small triangular or conical red mountain, perhaps a little white in the interior. These were the appearances seen instantly after the formation of the totality.

"I employed myself in an attempt to delineate roughly the appearances on the western limb, and I took a hasty view of the country; and I then examined the moon a second time. I believe (but I did not carefully remark) that the prominences *a b c* had increased in height; but *d* had now disappeared, and a new one *e* had risen up. It was impossible to see this change without feeling the conviction that the prominences belonged to the sun and not to the moon.

“I again looked round, when I saw a scene of unexpected beauty. The southern part of the sky, as I have said, was covered with uniform white cloud; but in the northern part were detached clouds upon a ground of clear sky. This clear sky was now strongly illuminated, to the height of 30° or 35° , and through almost 90° of azimuth, with rosy-red light shining through the intervals between the clouds. I went to the telescope, with the hope that I might be able to make the polarisation-observation, (which, as my apparatus was ready to my grasp, might have been done in three or four seconds,) when I saw that the *sierra*, or rugged line of projections, shown at *f*, had arisen. This *sierra* was more brilliant than the other prominences, and its colour was nearly scarlet. The other prominences had perhaps increased in height, but no additional new ones had arisen. The appearance of this *sierra*, nearly in the place where I expected the appearance of the sun, warned me that I ought not now to attempt any other physical observation. In a short time the white sun burst forth, and the corona and every prominence vanished.

“I withdrew from the telescope and looked round. The country seemed, though rapidly, yet half unwillingly, to be recovering its usual cheerfulness. My eye, however, was caught by a duskiness in the south-east, and I immediately perceived that it was the eclipse-shadow in the air travelling away in the direction of the shadow's path. For at least six seconds this shadow remained in sight, far more conspicuous to the eye than I had anticipated.”

30. Owing to the unfavourable state of the atmosphere, the observations of the other members of the Admiralty party were not so satisfactory as those of its chief. Nevertheless, both observers saw the red prominences, though imperfectly, as compared with the results of the observations of the Astronomer Royal. Baily's beads were seen by Mr. Dunkin, as well before as after the total obscuration. Their appearance was of intense brilliancy, compared by the observer to a diamond necklace. Their effect on the observer was “quite overpowering,” being unprepared for a sight so magnificent.

At Christianstad, the planets Venus, Mercury, and Jupiter, and the stars Arcturus and Vega, were visible during the totality of the eclipse.

31. Mr. W. Gray, stationed at Tune, near Sarpsborg, saw the beads, both before and after the total obscuration. He saw four of the red projections, three of which are represented in fig. 14, the fourth resembling *c* and *d* in form, and diametrically opposite to *a* in position on the moon's limb.

ECLIPSES.

During the totality, the light seemed like that of an evening in August at an hour and a half after sunset.

32. Messrs. Stephenson and Andrews, at Fredrichsvaarn, saw Baily's beads both before and after the total obscuration. The

Fig. 14.



Fig. 15.



crescent, before disappearing, was seen as a fine thread of light, which broke up into fragments, and when it re-appeared, it gave the idea of globules of mercury rushing amongst each other along the edge of the moon. In a second or two after the disappearance of the crescent, a rose-coloured flame shot out from the limb of the moon, which in form resembled a sickle (see fig. 15). It increased rapidly, and then two other rose-coloured prominences, above and below it, started out, differing in shape, but evidently of the same character. Besides these, there were, as well between them as elsewhere, around the moon's edge other lurid points and other indistinct lines. The height of the principal prominence was estimated at about the

Fig. 16.



twentieth of the moon's diameter, that is, about $1\frac{1}{2}'$. The chief prominences looked like burning volcanoes, and the lurid points and lines reminded the observers of dull streams of cooling lava.

33. Mr. Lassell, at Trollhättan Falls, having heard the red prominences seen in former total eclipses described as faint appearances, saw with astonishment around the dark disc of the moon, after the commencement of total obscuration, prominences of the most brilliant lake colour,—a splendid pink, quite defined and hard, fig. 16. They appeared not to be absolutely quiescent. The observer judged from their appearance that they belonged to the sun, and not to the moon.

34. Mr. Hind, at Ravelsborg, near Engelholm, saw the beads, both before and after the total obscuration, in such a manner as to leave no doubt of their cause being that already explained. In five seconds after the commencement of the total obscuration, the corona or glory around the moon's disc was seen. Its colour seemed to be that of tarnished silver, brightest next the moon's limb, and gradually fading to a distance equal to one-third of her diameter, where it became confounded with the general tint of the heavens. Appearances of radiation are mentioned, similar to those described by Professor Airy.

"On first viewing the sun," says Mr. Hind, "without the dark glass after the commencement of totality, the rose-coloured prominences immediately caught my eye, and others were seen a few seconds later (fig. 17, p. 177). The largest and most remarkable of them was situate about 5° north of the parallel of declination, on the western limit of the moon; it was straight through two-thirds of its length, but curved like a sabre near the extremity, the concave edge being towards the horizon. The edges were of a full rose-pink, the central parts plainer, though still pink.

"Twenty seconds, or thereabouts, after the disappearance of the sun, I estimated its length at $45''$ of arc, and on attentively watching it towards the end of totality, I saw it materially lengthened (probably to $2'$), the moon having apparently left more and more of it visible as she travelled across the sun. It was always curved, and I did not remark any change of form, nor the slightest motion during the time the sun was hidden. I saw this extraordinary prominence *four seconds after the end of totality*, but at this time it appeared detached from the sun's limb, the strong white light of the corona intervening between the limb and the base of the prominence.

"About 10° south of the above object I saw, during the totality, a detached triangular spot of the same rose colour, suspended, as it were, in the light of the corona, which gradually receded from the moon's dark limb, as she moved onwards, and was, therefore, clearly connected with the sun. Its form and position, with respect to the large prominence, continued exactly the same so long as I observed it. On the south limb of the moon appeared a long range of rose-coloured flames, which seemed to be affected with a tremulous motion, though not to any great extent.

"The bright rose-red of the tops of these projections gradually faded towards their bases, and along the moon's limb appeared a bright narrow line of a deep violet tint: not far from the western extremity of this long range of red flames was an isolated prominence, about $40''$ in altitude, and another of similar size and form, at an angle of 145° from the north towards the east: the

moon was decidedly reddish purple at the beginning of totality, but the reddish tinge disappeared before its termination, and the disc assumed a dull purple colour. A bright glow, like that of twilight, indicated the position where the sun was about to emerge, and three or four seconds later the beads again formed, this time instantaneously, but less numerous, and even more irregular, than before. In five seconds more the sun reappeared as a very fine crescent on the sudden extinction of the beads."



Fig. 17.



Fig. 18.

ECLIPSES.

CHAPTER II.

35. Observations of Mr. Dawes near Engelholm.—36. Effects of total obscuration on surrounding objects and scenery.—37. Evidence of a solar atmosphere.—38. Probable causes of the red emanations in solar eclipses. LUNAR ECLIPSES: 39. The earth's conical shadow.—40. Its section may be regarded as a dark disc moving on the firmament.—41. Conditions which determine lunar eclipses.—42. Lunar ecliptic limits.—43. Greatest duration of total lunar eclipses.—44. Effects of the earth's penumbra.—45. Effects of refraction of the earth's atmosphere in total lunar eclipse.—46. Lunar disc visible during total obscuration.

35. MR. DAWES near Engelholm observed the beads, and found all the circumstances attending their appearance, such as to leave no doubt as to the truth of the cause generally assigned to them. He observed the corona, a few seconds after the commencement of the totality, and estimated its extreme breadth at half the moon's diameter, the brightness being greatest near the moon's limb, and gradually decreasing outwards. The phenomena of the red protuberances, witnessed by Mr. Dawes, are so clearly and satisfactorily described by him, that we think it best here to give the account of them in his own words:—

“Throughout the whole of the quadrant, from north to east, there was no visible protuberance, the corona being uniform and uninterrupted. Between the east and south points, and at an angle of about 170° from the north point, appeared a large red prominence of a very regular conical form, fig. 18. When first seen, it might be about $1\frac{1}{2}'$ in altitude from the edge of the moon, but its length diminished as the moon advanced.

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"The position of this protuberance may be inaccurate to a few degrees, being more hastily noticed than the others. It was of a deep rose colour, and rather paler near the middle than at the edges.

"Proceeding southward, at about 145° from the north point commenced a low ridge of red prominences, resembling in outline the tops of a very irregular range of hills. The highest of these probably did not exceed $40''$. This ridge extended through 50° or 55° , and reached, therefore, to about 197° from the north point, its base being throughout formed by the sharply-defined edge of the moon. The irregularities at the top of the ridge seemed to be permanent, but they certainly appeared to undulate from the west towards the east; probably an atmospheric phenomenon, as the wind was in the west.

"At about 220° commenced another low ridge of the same character, and extending to about 250° , less elevated than the other, and also less irregular in outline, except that at about 225° a very remarkable protuberance rose from it to an altitude of $1\frac{1}{2}'$, or more. The tint of the low ridge was a rather pale pink; the colour of the more elevated prominence was decidedly deeper, and its brightness much more vivid. In form it resembled a *dog's tusk*, the convex side being northwards, and the concave to the south. The apex was somewhat acute. This protuberance, and the low ridge connected with it, were observed and estimated in height towards the end of the totality.

"A small double-pointed prominence was noticed at about 255° , and another low one with a broad base, at about 263° . These were also of the rose-coloured tint, but rather paler than the large one at 225° .

"Almost directly preceding, or at 270° , appeared a bluntly triangular pink body, *suspended*, as it were, in the corona. This was separated from the moon's edge when first seen, and the separation increased as the moon advanced. It had the appearance of a large conical protuberance, whose base was hidden by some intervening soft and ill-defined substance, like the upper part of a conical mountain, the lower portion of which was obscured by clouds or thick mist. I think the apex of this object must have been at least $1'$ in altitude from the moon's limb when first seen, and more than $1\frac{1}{2}'$ towards the end of total obscuration. Its colour was pink, and I thought it paler in the middle.

"To the north of this, at about 280° or 285° , appeared the most wonderful phenomenon of the whole. A red protuberance, of vivid brightness and very deep tint, arose to a height of, perhaps, $1\frac{1}{2}'$ when first seen, and increased in length to $2'$, or more, as the moon's progress revealed it more completely. In shape it some-

what resembled a *Turkish cimeter*, the northern edge being convex, and the southern concave. Towards the apex it bent suddenly to the south, or upwards, as seen in the telescope. Its northern edge was well defined, and of a deeper colour than the rest, especially towards its base. I should call it a *rich carmine*. The southern edge was less distinctly defined, and decidedly paler. It gave me the impression of a somewhat conical protuberance, partly hidden on its southern side by some intervening substance of a soft or flocculent character. The apex of this protuberance was paler than the base, and of a purplish tinge, and it certainly had a flickering motion. Its base was, from first to last, sharply bounded by the edge of the moon. To my great astonishment, this marvellous object *continued visible for about five seconds*, as nearly as I could judge, *after the sun began to reappear*, which took place many degrees to the south of the situation it occupied on the moon's circumference. It then rapidly faded away, *but it did not vanish instantaneously*. From its extraordinary size, curious form, deep colour, and vivid brightness, this protuberance absorbed much of my attention; and I am, therefore, unable to state precisely what changes occurred in the other phenomena towards the end of the total obscuration.

"The arc, from about 283° to the north point, was entirely free from prominences, and also from any roseate tint."

36. Although the different parties of observers scattered over the path of the moon's shadow were not equally fortunate in having a clear unclouded sky, they were all enabled to observe and record the effects of the total obscuration upon the surrounding objects and country. Dr. Robertson of Edinburgh, Dr. Robinson of Armagh, and some others, witnessed the eclipse from an island off the coast of Norway, in lat. $61^{\circ} 21'$, at a point in the path of the axis of the shadow. The precursory phenomena corresponded with those described by other observers. The atmosphere was, however, obscured by clouds, which appeared to rush down in streams from the place of the sun. The sea-fowl flocked to their customary places of rest and shelter in the rocks. The darkness at the moment of total obscuration was sudden, but not absolute; for the clouds had left an open strip of the sky, which assumed a dark lurid orange, which changed to greenish colour in another direction, and shed upon persons and objects a faint and unearthly light. Lamps and candles, seen at fifty or sixty yards' distance, were as visible as in a dark night, and the redness of their light presented a strange contrast with the general green hue of everything around them. "The appearance of the country," says Dr. Robertson, "seen through the lurid opening under the clouds, was most appalling. The distant peaks of the Tostedals and

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Dorieffeld mountains were seen still illuminated by the sun, while we were in utter darkness. Never before have we observed all the lights of heaven and earth so entirely confined to one narrow stripe along the horizon,—never that peculiar greenish hue, and never that appearance of outer darkness in the place of observation, and of excessive distance in the verge of the horizon, caused in this case by the hills there being more highly illuminated as they receded, by a less and less eclipsed sun."

Mr. Hind says, that during the obscuration "the entire landscape was overspread with an unnatural gloom; persons around him assumed an unearthly cadaverous aspect; the distant sea appeared of a lurid red; the southern heavens had a sombre purple hue, the place of the sun being indicated only by the CORONA; the northern heavens had an intense violet hue, and appeared very near. On the east and west of the northern meridian, bands of light of a yellowish crimson colour were seen, which gradually faded away into the unnatural purple of the sky at greater altitudes, producing an effect that can never be effaced from the memory, though no description could give a just idea of its awful grandeur."

At several places in Prussia, where the heavens were unclouded during the total obscuration, a great number of the more conspicuous stars, as well as the planets Jupiter, Venus, and Mercury, were visible. Several flowering plants were observed to close their blossoms, birds which had been previously flying about disappeared, and domestic fowls went to roost.

37. Many of the phenomena attending total solar eclipses afford strong corroboratory evidence of the existence of a solar atmosphere, extending to a vast height above the luminous coating of the sun.

The corona, or bright ray or glory, surrounding the dark disc of the moon where it covers the sun, is observed to be concentric with the moon only at the moment when the latter is concentric with the sun. In other positions of the moon's disc, it appears to be concentric with the sun. This would be the effect produced by a solar non-luminous atmosphere faintly reflecting the sun's light.

38. It appears to be agreed generally among astronomers that the red emanations above described are solar, and not lunar. If they be admitted then to be solar, it is scarcely possible to imagine them to be solid matter, notwithstanding the apparent constancy of their form in the brief interval during which at any one time they are visible, for the entire duration of their visibility has never yet been so much as four minutes. To admit the possibility of their being solar mountains projecting above the luminous atmosphere surrounding the sun, and rising to the height

LUNAR ECLIPSES.

in the exterior and non-luminous atmosphere forming the corona necessary to explain their appearance, we must suppose their height to amount to nearly a twentieth part of the sun's diameter, that is to 44000 miles.

The fact that they are gaseous and not solid matter appears, therefore, to be conclusively established by their enormous magnitude, the great height above the surface of the sun at which they are placed, their faint degree of illumination, and the circumstances of their being sometimes detached at their base from the visible limb of the sun. These circumstances render it probable that these remarkable appearances are produced by cloudy masses of extreme tenuity, supported, and probably produced in an extensive spherical shell of non-luminous gaseous matter, surrounding and rising above the luminous surface of the sun to a great altitude.

LUNAR ECLIPSES.

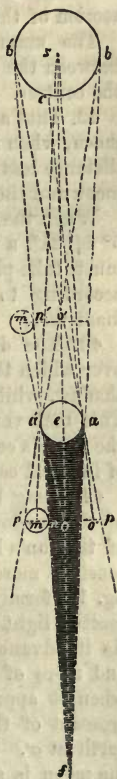
39. As the earth moves in its orbit round the sun it projects behind it a conical shadow, the axis of which is always directed to that point of the heavens which is in immediate opposition to the centre of the sun. A section of the sun *s*, and the earth *e*, and of the conical shadow made by a plane passing through the centres of the sun and earth, is shown in fig. 19.

It will be evident whenever the globe of the moon or any part of it enters within the limits of the conical shadow *a f a'*, it will be deprived of the sun's light, and will consequently be eclipsed; the circumstances, therefore, which determine lunar eclipses will depend upon the transverse section of the shadow at the moon's distance from the earth, this distance being about one-third of the total length of the conical shadow.

It is found by calculation that its greatest apparent diameter, as seen from the earth, is $45' 42''$, and its least $37' 49''$. Its mean magnitude is, therefore, $41' 45''$.

40. The section of the shadow may, therefore, be regarded as a dark disc, whose apparent semi-diameter varies between $37' 49''$ and $45' 42''$, and the true place of whose centre is a point on the ecliptic 180° behind the centre of the sun. A lunar eclipse is

Fig. 19.



ECLIPSES.

produced by the superposition, partial or total, of this disc on that of the moon, and the circumstances and conditions which determine such an eclipse are investigated upon the principles already explained.

41. By the solar tables, the apparent position of the centre of the sun, from hour to hour, may be ascertained, and the position of the centre of the section of the shadow may thence be inferred. From the lunar tables, the position of the moon's centre being in like manner determined, the distance between the centres of the section of the shadow and the moon's disc can be ascertained.

The magnitude of the eclipse is measured by the difference between the sum of the semi-diameters and the distance between the centres.

42. That a lunar eclipse may take place, it is necessary that the moon, when in opposition, should approach the ecliptic within a distance less than the sum of the apparent semi-diameters of the moon and the section of the shadow.

When the distance from the node at opposition is greater than $5^{\circ} 44' 21''$, a total eclipse cannot, and when less than $3^{\circ} 54' 5''$, it must, take place. Between these limits it may or may not occur, according to the magnitude of the parallax and apparent diameters.

43. The duration of a total eclipse depends on the distance over which the centre of the moon's disc moves relatively to the shadow, while passing from the first to the last internal contact. This may vary from 0, to twice the greatest possible distance of the moon's centre from the centre of the shadow, at the moment of internal contact.

44. Long before the moon enters within the sides of the cone of the shadow it enters the penumbra, and is partially deprived of the sun's light, so as to render the illumination of its surface sensibly more faint. When once it passes within the line $a'p'$, fig. 19, forming the external limit of the penumbra, it ceases to receive light from that part of the sun which is near the limb b . As it advances closer to $a'f$, the edge of the true shadow, more and more of the solar rays are intercepted by the earth; and when it approaches the edge, it is only illuminated by a thin crescent of the sun, visible from the moon over the edge of the earth at a' . It might be thus inferred, that the obscuration of the moon is so extremely gradual, that it would be impossible to perceive the limitation of the shadow and penumbra. Nevertheless, such is the splendour of the solar light, that the thinnest crescent of the sun, to which the part of the moon's surface near the edge of the earth's shadow is exposed, produces a degree of illumination which contrasts so strongly with the shadow as to

the horizontal refraction. But the mean value of the horizontal refraction being $33'$, the mean value of the angle $m e m'$ will be $66'$. But since the greatest value of $m e o$ is $45' 42''$, it follows that the refracted ray $e m'$ will fall upon the section of the shadow at a point beyond its centre; and since the same will take place at all points round the shadow, it follows that the entire section will be more or less illuminated by the light thus refracted: the intensity of such illumination increases from the centre towards the borders.

46. When the moon's limb first enters the shadow at m , the contrast and glare of the part of the disc still enlightened by the direct rays of the sun render the eye insensible to the more feeble illumination produced upon the eclipsed part of the disc by the refracted rays. As, however, the eclipse proceeds, and the magnitude of the part of the disc directly enlightened decreases, the eye, partly relieved from the excessive glare, begins to perceive very faintly the eclipsed limb, which is nevertheless visible from the beginning in a telescope, in which it appears with a dark grey hue. When the entire disc has passed into the shadow, it becomes distinctly visible, showing a gradation of tints from a bluish or greenish on the outside to a gradually increasing red, which, further in, changes to a colour resembling that of incandescent iron when at a dull red heat. As the lunar disc approaches the centre of the shadow, this red line is spread all over it. Its illumination in this position is sometimes so strong as to throw a sensible shadow, and to render distinctly visible in the telescope the lineaments of light and shadow upon its surface.

These effects are altogether similar to the succession of tints developed in our atmosphere at sunset, and arise, in fact, from the same cause, operating, however, with a two-fold intensity. The solar rays traversing twice the thickness of air, the blue and green lights are more effectually absorbed, and a still more intense red is imparted to the tints transmitted. Without pursuing these consequences further here, the student will find no difficulty in tracing them in the effects of sunset and of sunrise, and of evening and morning twilight.

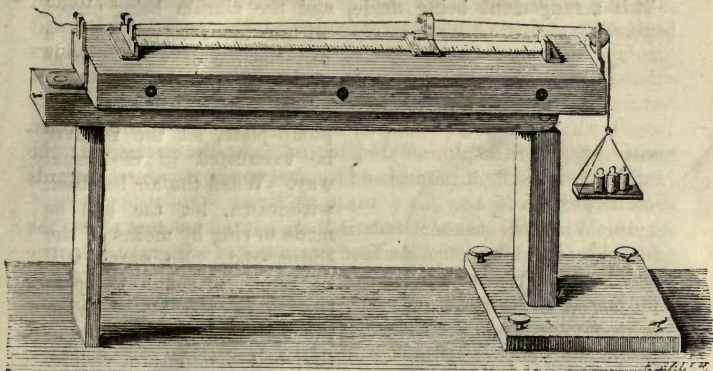


Fig. 2.—A MONOCHORD, OR SONOMETER.

SOUND.

1. Definition.—2. Air the conductor.—3. Sound progressive.—4. Breadth of sonorous waves.—5. Musical sounds, how characterised.—6. Pitch.—7. Loudness.—8. Timbre.—9, 10. Velocity.—11. Distances measured by sound.—12. Density of air affects loudness.—13. Effect of atmospheric agitation.—14. Sound conveyed through liquids.—15. Solids.—16. Effects of Elasticity of air.—17. Chladni's experiments.—18. Monochord.—19. Vibration of musical strings.—20. Cause of harmony shown.

1. SOUND is the sensation produced in the organs of hearing when they are affected by undulations transmitted to them through the atmosphere. These undulations are subject to an infinite variety of physical conditions, and each variety is followed by a different sensation.

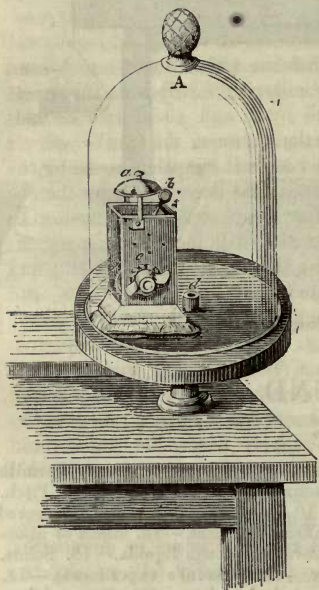
2. That the presence of air or other conducting medium is indispensable for the production of sound, is proved by the following experiment.

Let a small apparatus (fig. 1, p. 186) called an alarum, consisting of a bell *a*, which is struck by a hammer *b*, moved by clockwork, be placed under the receiver of an air-pump, through the top of which a rod slides, air-tight, the end of the rod being connected with a detent which governs the motion of the clockwork connected with the hammer. This rod can, by a handle placed outside the receiver, be made to disengage the detent, so as to make the bell ring whenever it is desired.

SOUND.

This arrangement being made, and the alarum being placed

Fig. 1.



within the receiver, upon a soft cushion of wool *e*, so as to prevent the vibration from being communicated to the pump-plate, let the receiver be exhausted in the usual way. When the air has been withdrawn, let the bell be made to ring by means of the sliding-rod. No sound will be heard, although the percussion of the tongue upon the bell, and the vibration of the bell itself, are visible. Now if a little air be admitted into the receiver, a faint sound will begin to be heard, and this sound will become gradually louder in proportion as the air is gradually readmitted.

In this case the vibrations which directly act upon the ear are not those of the air contained in the receiver. These latter act upon the receiver itself and the pump-

plate, producing in them sympathetic vibration; and those vibrations impart vibrations to the external air which are transmitted to the ear.

If in the preceding experiment a cushion had not been interposed between the alarum and the pump-plate, the sound of the bell would have been audible, notwithstanding the absence of air from the receiver. The vibration in this case would have been propagated, first from the bell to the pump-plate and to the bodies in contact with it, and thence to the external air.

3. Since the propagation of undulations through the atmosphere is progressive, an interval of time, more or less, must elapse between the vibration of the sounding body and the perception of the sound by a hearer, and such interval will be proportionate to the distance of the hearer from the sounding body, and to the velocity with which sound is propagated through the intervening medium. This progressive propagation of sound can be directly proved by experiment.

SONOROUS WAVES.

Let a series of observers, A, B, C, D, &c., be placed in a line, at distances of about 1000 feet asunder, and let a pistol be discharged at P, about 1000 feet from the first observer.

P A B C D E F

This observer will see the flash of the pistol about one second before he hears the report. The observer B will hear the report one second after it has been heard by A, and about two seconds after he sees the flash. In the same manner, the third observer at C will hear the report one second after it has been heard by the observer at B, and two seconds after it has been heard by the observer at A, and three seconds after he perceives the flash. In the same way, the fourth observer at D will hear the report one second later than it was heard by the third observer at C, and three seconds later than it was heard by the observer at A, and four seconds after he perceives the flash.

Now it must be observed, that at the moment the report is heard by the second observer at B, it has ceased to be audible to the first observer at A; and when it is heard by the third observer at C, it has ceased to be heard by the second observer at B, and so forth. It follows, therefore, from this, that sound passes through the air, not instantaneously, but progressively, and at a uniform rate.

4. As the sensation of sound is produced by the wave of air impinging on the tympanum of the ear, exactly as the momentum of a wave of the sea would strike the shore, it follows that the interval between the production of sound and its sensation, is the time which such a wave would take to pass through the air from the sounding body to the ear; and since these waves are propagated through the air in regular succession, one following another without overlaying each other, the breadth of a wave may always be determined if we take the number of vibrations which the sounding body makes in a second, and the velocity with which the sound passes through the air. If, for example, it be known that in a second a musical string makes 500 vibrations, and that the sound of this string takes a second to reach the ear of a person at a distance of 1000 feet, there are 500 waves in the distance of 1000 feet, and consequently each wave measures two feet.

The velocity of the sound, therefore, and the rate of vibration, are always sufficient data by which the length of a sonorous wave can be computed.

5. It has not been ascertained, with any clearness or certainty, by what physical distinctions vibrations which produce common sounds or noises are distinguished from such as produce musical

sounds. It is nevertheless certain, that all vibrations, in proportion as they are regular, uniform, and equal, produce sounds proportionably more agreeable and musical.

Sounds are distinguished from each other by their *pitch* or *tone*, in virtue of which they are high or low; by their *intensity*, in virtue of which they are loud or soft; and by a property expressed in French by the word *timbre*, which we shall here adopt in the absence of any English equivalent.

6. The pitch or tone of a sound is grave or acute. In the former case it is low, and in the latter high, in the musical scale.

The more rapid the vibrations are, the more acute will be the sound. A bass note is produced by vibrations much less rapid than a note in the treble.

All vibrations which are performed at the same rate produce waves of equal length and sounds of the same pitch.

7. The intensity of a sound, or its degree of loudness, depends on the force with which the vibrations of the sounding body are made.

8. The timbre of a sound is not easily explained, and still less easily can the physical conditions on which it depends be ascertained. If we hear the same musical note produced with the same degree of loudness in an adjacent room successively upon a flute, a clarionet, and a hautboy, we shall, without the least hesitation, distinguish the one instrument from the other. Now this distinction is made by observing some peculiarity in the notes produced, yet the notes shall be the same, and be produced with equal loudness.

9. It is manifest from the absence of all confusion in the effects of music, at whatever distance it may be heard, that in the same medium all sounds have the same velocity. If the different notes simultaneously produced by the various instruments of an orchestra moved with different velocities through the air, they would be heard by a distant auditor at different moments, the consequence of which would be, that a musical performance would, to the auditors, save those in immediate proximity with the performers, produce the most intolerable confusion and cacophony; for different notes produced simultaneously, and which, when heard together, form harmony, would at a distance be heard in succession; and sounds produced in succession would be heard as if produced together, according to the different velocities with which each note would pass through the air.

10. The velocity of sound varies with the elasticity of the medium by which it is propagated. Its velocity, therefore, through the air will vary, more or less, with the barometer and thermometer.

The experimental methods which have been adopted to ascertain the velocity of sound are similar in principle to those which have

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been briefly noticed by way of illustration. The most extensive and accurate system of experiments which have been made with this object, were those made at Paris by the Board of Longitude in the year 1822. The sounding bodies used on this occasion, were pieces of artillery charged with from two to three pounds of powder, which were placed at Villejuif and Montlhéry. The experiments were made at midnight, in order that the flash might be more easily and accurately noticed. They were conducted by MM. Prony, Arago, Mathieu, Humboldt, Gay Lussac, and Bouvard. The result of these experiments was, that when the barometer was at 29·8 inches, and the thermometer at 61°, the velocity of sound was 1118·4 feet per second.

According to the theory of Laplace, the velocity of sound increases at the rate of 1·11 feet per second for every degree in the rise, and decreases at the same rate for each degree in the fall of the thermometer. Hence it appears that the velocity of sound at 32° is 1086·2 feet per second. For all practical purposes, it is sufficiently exact to take 1120 feet as the velocity of sound at 62°, and allow thirteen inches for every variation of a degree in temperature.

11. The production of sound is in many cases attended with the evolution of light, as, for example, in fire-arms and explosions generally, and in the case of atmospheric electricity. In these cases, by noting the interval between the flash and the report, and multiplying the number of seconds in each interval by the number of feet per second in the velocity of sound, the distance can be ascertained with great precision. Thus, if a flash of lightning be seen ten seconds before the thunder which attends it is heard, and the atmosphere be in such condition that the velocity of sound is 1120 feet per second, it is evident that the distance of the cloud in which the electricity is evolved must be 11200 feet.

12. The same sounding body will produce a louder or lower sound, according as the density of the air which surrounds it is increased or diminished. In the experiment already explained, in which the alarum was placed under an exhausted receiver, the sound increased in loudness as more and more air was admitted within the receiver. If the alarum had been placed under a condenser, and highly compressed air collected round it, the sound would be still further increased.

When persons descend to any considerable depth in a diving-bell, the atmosphere around them is compressed by the weight of the column of water above them. In such circumstances a whisper is almost as loud as the common voice in the open air, and when one speaks with the ordinary force it produces an effect so loud as to be painful.

On the summit of lofty mountains, where the barometric column

SOUND.

falls to one-half its usual elevation, and where therefore the air is highly rarefied, sounds are greatly diminished in intensity. Persons who ascend in balloons find it necessary to speak with much greater exertion, and, as would be said, louder, in order to render themselves audible. When Saussure ascended Mont Blanc, he found that the report of a pistol was not louder than a common cracker.

13. Violent winds and other atmospheric agitations affect the transmission of sound. When a strong wind blows from the hearer towards the sounding body, a sound often ceases to be heard which would be distinctly audible in a calm. A tranquil and frosty atmosphere placed over a smooth and level surface is favourable to the transmission of sound. Lieutenant Forster held a conversation with a person on the opposite side of the harbour of Port Bowen, in the third polar expedition of Sir Edward Parry, the distance between the speakers being more than a mile.

It is said that the sound of the cannon at the battle of Waterloo was heard at Dover, and that the cannon in naval engagements in the Channel have been heard in the centre of England.

14. Liquids are also capable of propagating sound. Divers can render themselves audible at the surface of the water; and stones or other objects struck together at the bottom produce a sound audible at the surface.

It appears from the experiments of M. Colladon, made at Geneva, that sounds are transmitted through water to great distances with greater force than through air. A blow struck under the water of the Lake of Geneva was distinctly heard across the whole breadth of the lake, a distance of nine miles.

Solid bodies, such as walls or buildings interposed between the sounding body and the hearer, diminish the loudness of the sound, but do not obstruct it when the sound is made in air; but it appears from the experiments of M. Colladon, that the interposition of such obstacles almost destroys the transmission of sound in water.

15. Solids which possess elasticity have likewise the power of propagating sound. If the end of a beam composed of any solid possessing elasticity be lightly scratched or rubbed, the sound will be distinct to an ear placed at the other end, although the same sound would not be audible to the ear of the person who produces it, and who is contiguous to the place of its origin.

The earth itself conducts sound, so as to render it sensible to the ear when the air fails to do so. It is well known, that the approach of a troop of horse can be heard at a distance by putting the ear to the ground. In volcanic countries, it is said that the rumbling noise which is usually the prognostic of an eruption is

first heard by the beasts of the field, because their ears are generally near the ground, and they then by their agitation and alarm give warning to the inhabitants of the approaching catastrophe. Savage tribes practise this method of ascertaining the approach of persons from a great distance.

16. The velocity with which sound is transmitted through the air varies with its elasticity; and where different strata are rendered differently elastic by the unequal radiation of heat, the agency of electricity, or other causes, the transmission of sound will be irregular. In passing from stratum to stratum differing in elasticity, the speed with which sound is propagated is not only varied, but the force of the intensity of the undulations is diminished by the combined effects of reflection and interference, so that the sound, on reaching the ear, after passing through such varying media, is often very much diminished.

The fact, that distant sounds are more distinctly heard by night than by day, may be in part accounted for by this circumstance, the strata of the atmosphere being during the day exposed to vicissitudes of temperature more varying than during the night.

17. The solids composing the body of an animal are capable of transmitting the sonorous undulations to the organ of hearing, even though the air surrounding that organ be excluded from communicating with the origin of the sound.

Chladni showed that two persons stopping their ears could converse with each other by holding the same stick between their teeth, or by resting their teeth upon the same solid. The same effect was produced when the stick was pressed against the breast or the throat, and other parts of the body.

If a person speak, directing his mouth into a vessel composed of any vibratory substance, such as glass or porcelain, the other stopping his ears, and touching such vessel with a stick held between his teeth, he will hear the words spoken.

The same effect will take place with vessels composed of metal or wood.


If two persons hold between their teeth the same thread, stopping their ears, they will hear each other speak, provided the thread be stretched tight.


18. Of the various forms of apparatus which have been contrived for the production of musical sounds, with a view to the experimental illustration of their theory, that which is best adapted for this purpose, called a *monochord* or *sonometer* (fig. 2) consists of a string of catgut or wire attached to a fixed point, carried over a pulley, and stretched by a known weight. Under the string is a hollow box or sounding-board, to the frame of which the pulley is attached. The string

rests upon two bridges, one of which is fixed, and the other can be moved with a sliding motion to and fro, so as to vary at pleasure the length of the part of the string included between the two bridges.

A divided scale is placed under them, so that the length of the vibrating part of the string may be regulated at pleasure. By varying the weight, the tension of the string may be increased or diminished in any desired proportion. This may be accomplished with facility by circular weights which are provided for the purpose, and which may be slipped upon the stem of the weight. By means of this apparatus, the relation between the various notes of the musical scale and the rate of vibration by which they are respectively produced have been ascertained.

19. The rate of vibration of a string such as that of the monochord is inversely as its length, other things being the same. Thus, if its length be halved, its rate of vibration is doubled; if its length be diminished or increased in a threefold proportion, its rate of vibration will be increased or diminished in the same proportion; and so forth.

Let the bridges be placed at a distance from each other as great as the apparatus admits, and let the weight which stretches the string be so adjusted, that the note produced by vibrating the string shall correspond with any proposed note of the musical scale; such, for example, as , the low c of the treble clef.

This being done, let the movable bridge be moved towards the fixed bridge, continually sounding the string until it produces the octave above the note first sounded, that is, until it produces the middle c  of the treble.

If the length of the string be now ascertained by reference to the scale of the monochord, it will be found to be precisely one-half its original length

20. Hence it follows, that the same string will sound an octave higher if the length is halved. But the rate of vibration will be doubled when the length of the string is halved. Hence it follows, that two sounds, one of which is an octave higher than the other, will be produced by vibrations, the rate of which will be in the proportion of 2 to 1; and, consequently, the length of the undulation producing the lower note will be double that of the undulation producing the higher note.

By like experiments it is shown that the more frequent the coincident vibrations are the more perfect is the harmony, and the less frequent they are the more discordant are the notes.

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